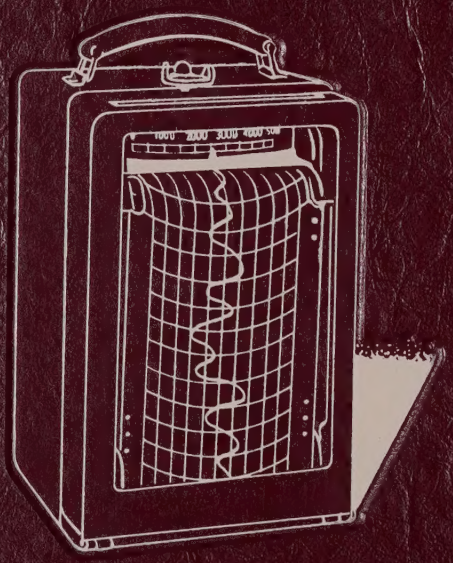
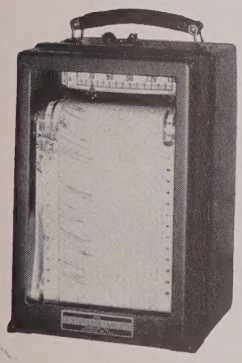
ESTERLINE-ANGUS



"The Meter With a Record"
For Over 50 Years

ESTERLINE-ANGUS

Products Catalog



"The Meter With a Record"
For Over 50 Years

BRENNER-FIEDLER & ASSOC., INC.
ENGINEERING REPRESENTATIVES
7563 Melrose Ave.
Los Angeles 46, Calif.
OL. 1-4300

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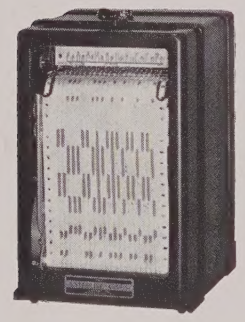
THE ESTERLINE-ANGUS CO., INC.
Pioneers in the Manufacture of Graphic Instruments
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

For over fifty years, **this company has built the finest direct-writing graphic instruments that the best materials and manufacturing techniques could produce. Our attention is directed solely toward producing high-quality, continuous-writing recorders built for low-cost operation rather than low initial price. That is what you, our customers, have repeatedly told us you want.**

We shall continually strive during our second half-century, to maintain E-A recorders in the position of leadership to which your acceptance of our past efforts has elevated them.



How to Use This Catalog

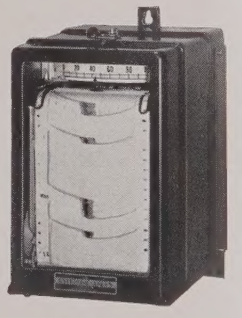
A recorder consists of three fundamental units: case, chart drive and measuring element. Each of the three units must be studied, in the selection of a recorder, so that the complete graphic instrument may best serve the purchaser.

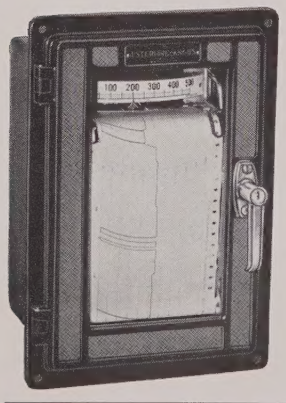
To assist in the selection of the proper components to make up the recorder, this catalog is divided into sections as shown in the table of contents. Suitable case and chart drive specifications should be obtained from sections 15 and 20. Then measuring element details, attachments and accessories should be determined from one of the remaining sections 30 through 80, and record charts selected from section 90.

Each catalog section carries an indexing spot, on all right-hand pages, corresponding to its listing in the Table of Contents.

PRICES Esterline-Angus instruments are built to so many different specifications that the calculation of price is sometimes complicated. Because of this, price lists on instruments are not available for general distribution. However, we will gladly quote prices, upon receipt of the technical information outlined at the end of each catalog section.

Price lists on charts, ink and other supplies such as pens, pen elements and inking tools, will be sent on request.





Product Representatives

This company earnestly desires that every instrument we sell shall accomplish the purpose for which it was purchased. To this end there are engineers in most principal cities, who understand our instruments and their correct application to a wide variety of technical, industrial, scientific and research problems.

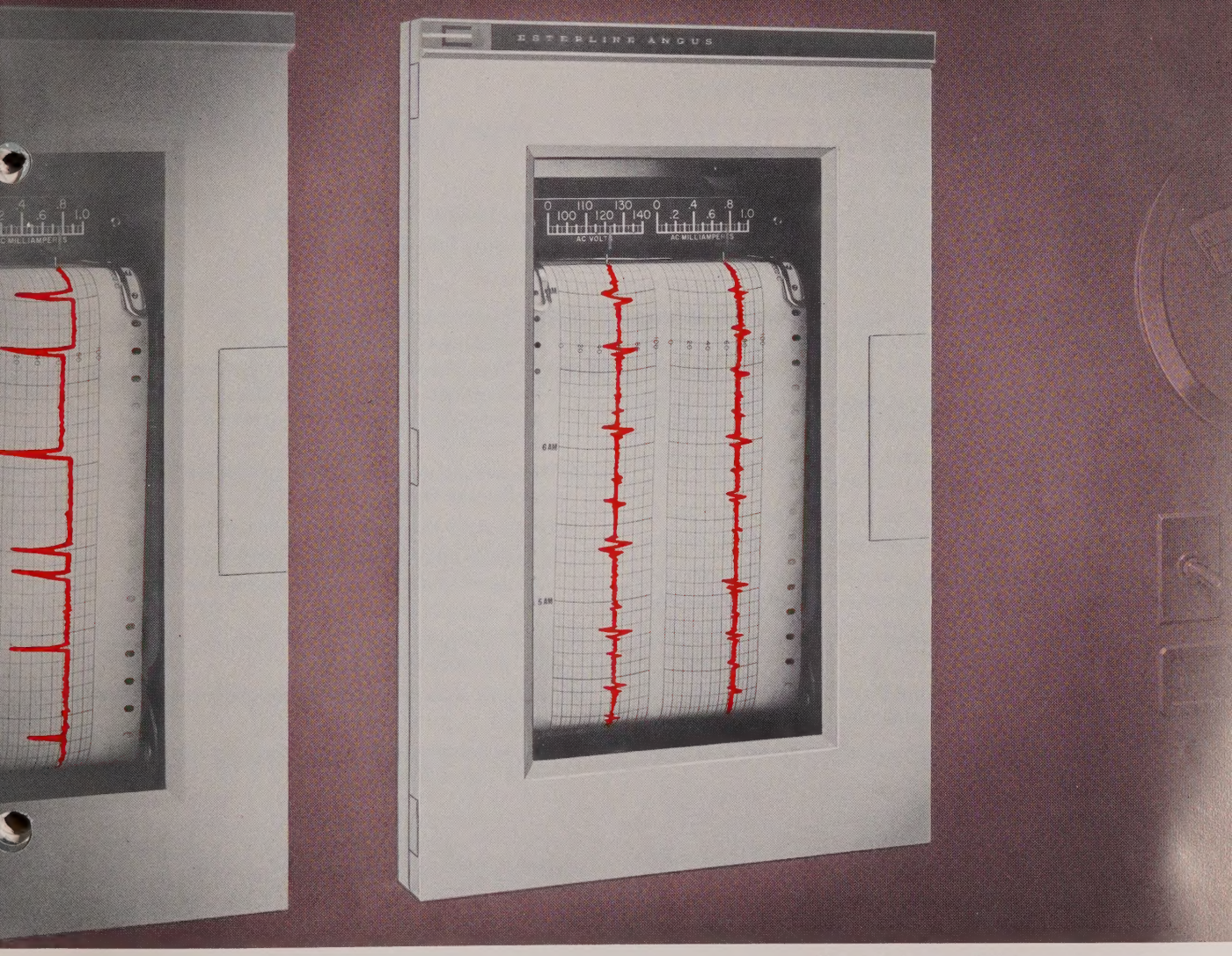
Your inquiries regarding prices or delivery may be addressed to the Esterline-Angus Product Representative or to the factory in Indianapolis. The Product Representative is trained in the use of our instruments and qualified to discuss your problems with you.

GUARANTEE

All Esterline-Angus instruments are guaranteed to be free from defects due to faulty material or workmanship, and any instrument proving defective within one year from date of shipment will be repaired or replaced free of charge, when returned to our works prepaid, provided the instrument has not been tampered with or misused. We do not assume responsibility for repairs made outside of our plant.

Printed in U.S.A., 10M

Catalog Section 10
(January 1957)



Modern flush case available in grey or charcoal.

New "602" Two-channel ESTERLINE ANGUS Recorder

● Here's a unique recording instrument that offers you two-for-your-money! It simultaneously records two channels of plotted data vs. time in the same space formerly required for one. Synchronized graphs are provided side-by-side on a single six-inch-wide chart. The recorder's two pens graph any value within the range of microamperes to kiloamperes . . . millivolts to kilovolts. It will also record watts or vars when used in connection with thermal convertors or Hall generators.

compact · lightweight · dependable · reasonably-priced

SEE *INSIDE* FOR ADDITIONAL INFORMATION, DIAGRAMS, SPECIFICATIONS

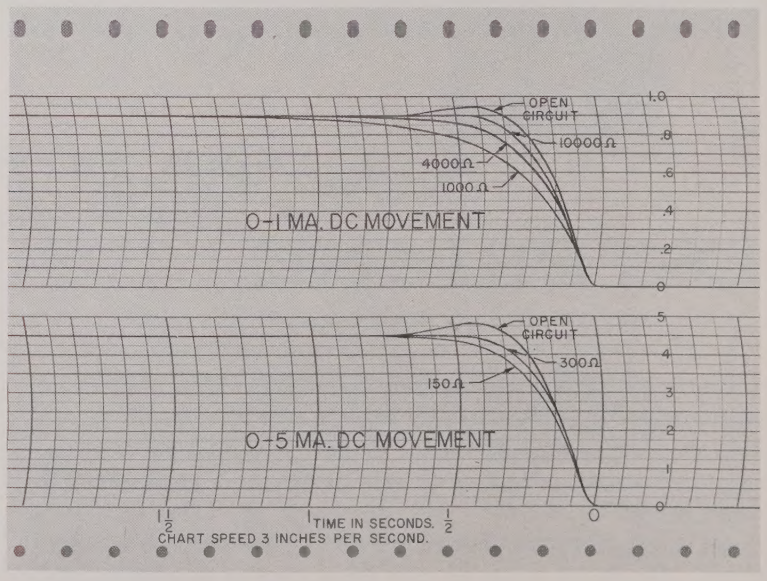
EXCLUSIVE FEATURES / *"602" two-channel recorder*

Fifteen good reasons why the new "602" Two-channel Esterline Angus Recorder gives you so much more added value for your money:

1. A product of Esterline Angus superior engineering and manufacturing, designed for many years' service —not early obsolescence.
2. All major parts and components made and assembled in the Esterline Angus plant by Master Craftsmen.
3. A minimum life expectancy of 100,000 hours, five times the life of many instruments.
4. Only recorder on the market today that's proven its ability to withstand the rigors of rough industrial use.
5. Modular construction: Chart drives, cases and measuring element assemblies completely interchangeable.
6. Chart consumption reduced over other recording means.
7. Uses an Esterline Angus chart drive proven by years of use to be of unequalled dependability.
8. Only half the panel board space required over other recording methods.
9. Easily maintained and serviced.
   a. One-piece writing element
   b. Fast chart threading from front of instrument
   c. Perfectly re-rolled charts time after time
   d. Non-spilling, throw-away inkwell (2 to 6-month capacity)
10. Best writing quality because pen writes up front on wrinkle-free chart.
11. Less weight than many recorders.
12. A complete line of accessories including an event pen, high speed chart drives and remote chart speed controls.
13. 1500-hour operation without attention of any kind. (¾" per hour chart speed)
14. Less cost than two recorders normally required to do the job.
15. Modern-styled flush case in grey or charcoal. Raymond Loewy design.

RESPONSE CURVES

"602" two-channel recorder



These families of curves illustrate the response time of typical milliammeters available in the Two-channel Recorder. In making each curve, the current was changed instantaneously from 0 to nine-tenths of full scale. Chart speed in these examples was three inches per second. Accuracy of DC milliammeters is 1% of full scale.

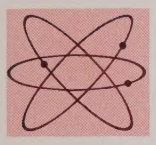
ESTERLINE ANGUS

APPLICATIONS

electric utilities and large industrials

Bus volts and amperes on one chart
Two bus voltages or 2 currents on one chart
Both voltages on a single-phase, three-wire system
Watts and vars (using microammeters and thermal convertors or Hall generators)

nuclear studies



Comparative records of two radiation sources on one chart, or of two types of radiation simultaneously

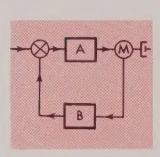
aerial surveys

Aircraft height vs. intensity of radiation from earth's surface

microwave and radio field strength

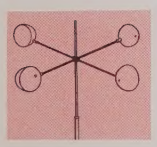
Comparison of two received signals, or of transmitted and received signal, on one chart

servo studies



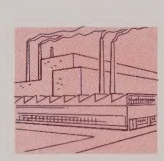
Physical movement of control device vs. response of controlled member

meteorological studies



Wind speed and direction
Two wind speeds
Wind speed and sunshine intensity

steel mills



Current and voltage on large DC motors
Strip speed vs. motor current

welding studies

Arc current and voltage

anodizing and plating baths

Current and voltage

conveyor systems

Relative speeds of two conveyors, or a conveyor vs. machine speed

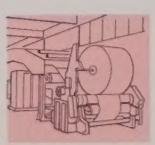
cement

Kiln speed vs. slurry feed

railroads

Train speed vs. traction motor current

strip mills—paper—steel—building materials



Thickness at center vs. edge

Excellence in graphic recording for over 50 years

SPECIFICATIONS / *"602" two-channel recorder*

measuring elements (ranges)

Uses two measuring elements (permanent-magnet moving coil type) which write completely independent records with pen and ink on adjacent two-inch sections of a six-inch-wide chart. AC current and voltage ranges are accommodated by means of a rectifier circuit. Ranges suggested for either the left-hand or right-hand channel are given in the table below:

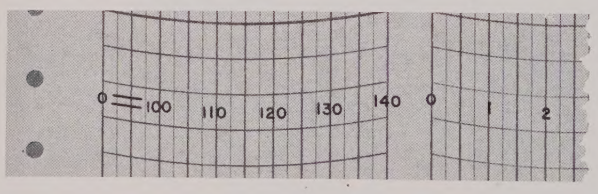
0-150 Volts AC
0-300 Volts AC
0-5 Amperes AC
0-10 Amperes AC
*0-50 Milliamperes AC
} 50-800 cycles

0-150 Volts DC
0-300 Volts DC
0-1 Milliamperes DC (1400 ohms internal resistance)
0-5 Milliamperes DC (65 ohms internal resistance)
0-50 Microamperes DC (employs a magnetic amplifier)
0-100 Millivolts DC (for use with 100 MV shunts, requires 150 MA DC)

*0-50 MA range for use with 50/100/200A: 50 MA Split Core current transformer.

expanded ranges

Expanded AC or DC voltage ranges are offered. Approximately the upper ¼ of the range will be expanded over the upper 80% of the channel width. Zero will be retained. The balance of the range will be uncalibrated and compressed into the lower 20% of the channel width. Shown below is a suggested expanded voltage range, 0-100—140 volts, 50-400 cycles:



zero and accuracy

Left-hand zero may be shifted to center zero on all ranges except those which are expanded. Operation at center zero cuts full scale range in half. Accuracy is 1% on many ranges, no less than 2% of full scale on any range.

right-hand event pen

This device will key other events to the main records. The pen is mounted to record in the right margin of the chart. It is operated by a rugged electro-magnet which can be rated for practically any AC or DC voltage.

cases

Portable, wall, flush and front switchboard cases are available. All but portable can also be furnished in a twin arrangement for mounting two two-channel recorders. Portable cases come in grey; flush cases come in grey or charcoal. All others are black. Flush cases have 120 volt, 60 cycle fluorescent lighting, but incandescent lighting can be furnished if desired.

chart drives

Three general classes are available: hand-wound spring, motor-wound spring, synchronous. Each type provides chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds to 3 inches per second can be easily accommodated.

charts

Charts are 6 inches wide and have two uniformly-divided channels. Listed below are several styles with time markings for operation at 3 inches per hour, which are available now. Others will be offered later. Many special designs can be supplied. Write, giving details.

Chart Number	Range Left Channel	Range Right Channel
31002-C	0-100	0-100
31006-C	0-150	0-150
31010-C	0-100	0-150
31011-C	0-100—140	0-5

how to order (specify)

1. Case Style (if flush, choose color).
2. Chart drive.
3. Measuring Element for Left-hand and Right-hand channel—Select range for each channel from table on this page. Write to us if the range you wish is not listed. Most requirements can be met.
4. Event Pen—Give electrical rating.
5. Chart Number.
6. Accessories and Attachments—Writing door, glass corner in case cover, chart inspector, carrying case.
7. Supplies—Charts, extra pen elements, pen point cleaner, writing fluid.

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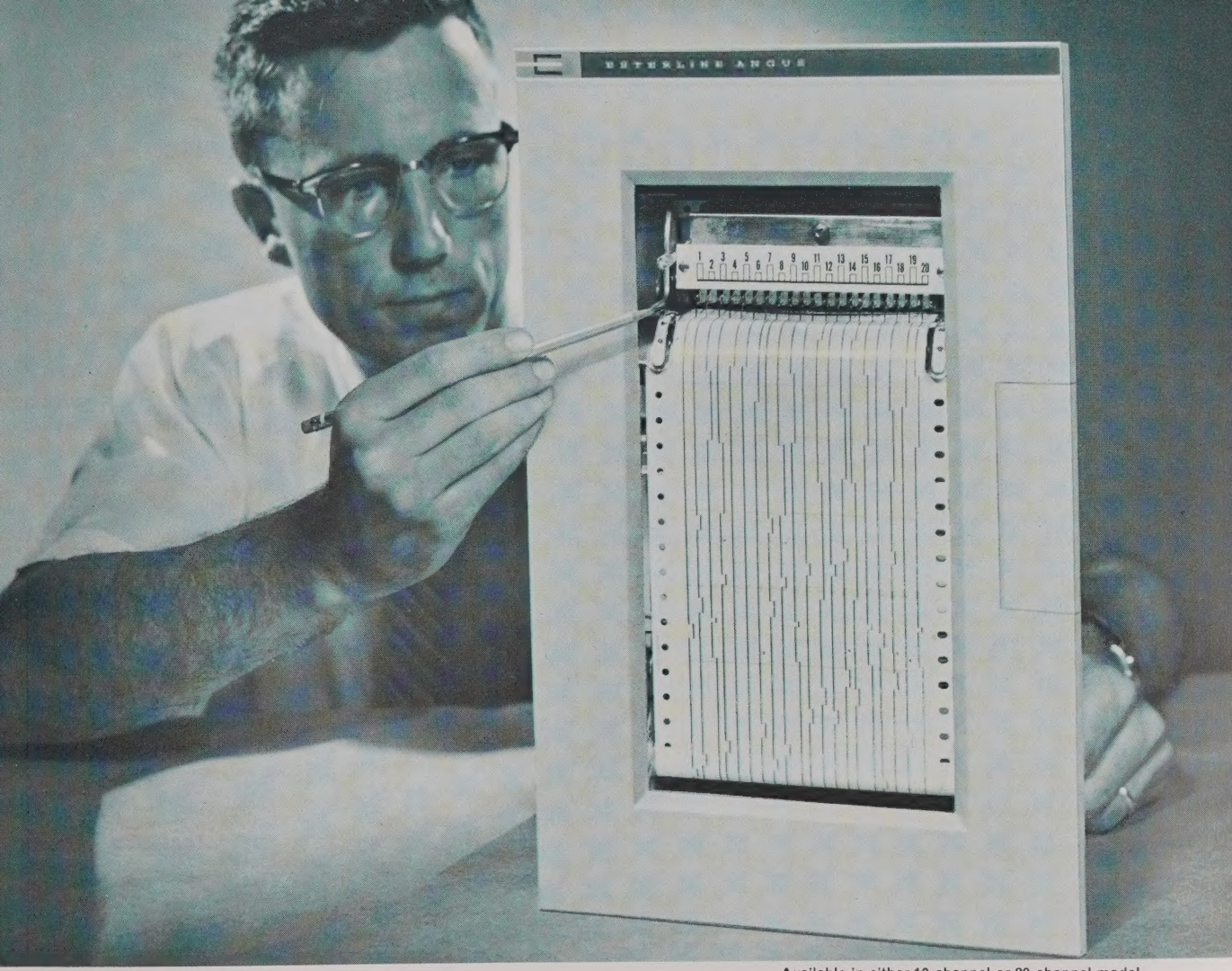
Form 6101 (10M)

Printed in U.S.A.



Available in either 10-channel or 20-channel model

New "620" Esterline Angus Event Recorder with Tempen*

● This amazing instrument simultaneously records "when," "how long" and "how many" on as many as 20 channels on a single six-inch-wide chart . . . *all without ink!* Instead of ink, it uses electrically-heated styluses of stainless steel . . . styluses that can endure 20 years of continuous operation and still respond in less than 1/20 of a second. The inkless event recorder also uses special chart paper with a non-wax finish, eliminating the danger of marred records caused by external heat, rough handling or strong light discoloration. The 10-channel model sells for less than $500; the 20-channel model for less than $575.

**inkless* writing method . . . operates more than 50 days without servicing or a change in charts

versatile · dependable · reasonably-priced

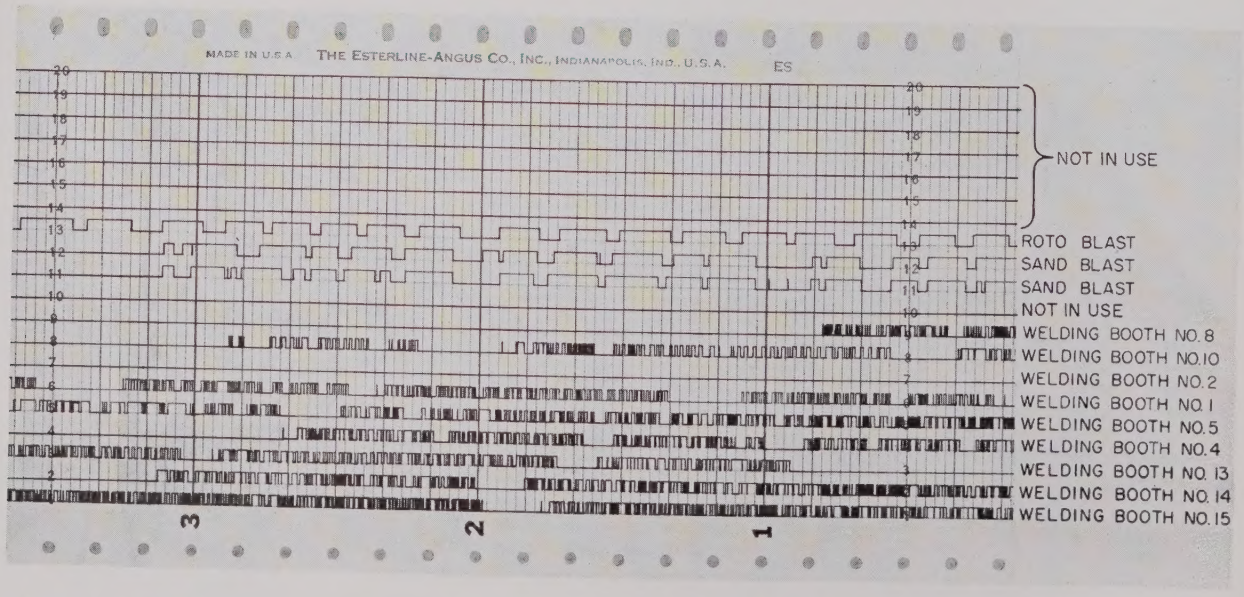
SEE *INSIDE* FOR ADDITIONAL INFORMATION, DIAGRAMS, SPECIFICATIONS

EXCLUSIVE FEATURES / *"620" with Tempen*

Ten good reasons why the new "620" Esterline Angus Event Recorder with Tempen gives you so much more added value for your money:

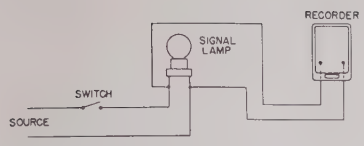
1. A product of Esterline Angus superior engineering and manufacturing, designed for many years' service—not early obsolescence.
2. All major parts and components made and assembled in the Esterline Angus plant by Master Craftsmen.
3. A minimum life expectancy of 100,000 hours, five times the life of many instruments.
4. Only recorder on the market today that's proven its ability to withstand the rigors of rough industrial use.
5. Unlike instruments employing electrostatic writing systems, this instrument produces records without smoke or fumes.
6. Uses an Esterline Angus chart drive proven by years of use to be of unequalled dependability.
7. Positive displacement of stylus occurs when signal is present . . . making it easy to recognize that an event has taken place.
8. Fifty-day operation without attention of any kind; no ink to spill, run or freeze.
9. Chart can be installed from front of instrument with a minimum of effort.
10. Modern-styled flush case in Esterline gray or charcoal. Raymond Loewy design.

APPLICATIONS / *"620" with Tempen*

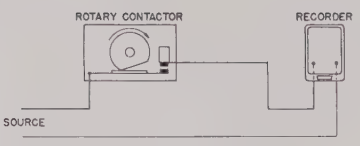


Channels 1 through 9 show the operation of welders in a steel fabricating plant. Channels 11, 12 and 13 show the active and idle time of casting cleaning machines. To provide for the future addition of more production equipment, channels 10, 14-20 are in the instrument but will not be used until needed. Thus the performance of eight more machines can be added to the record at any time.

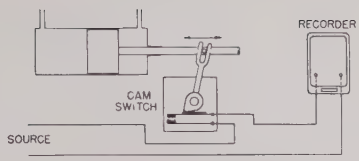
ESTERLINE ANGUS



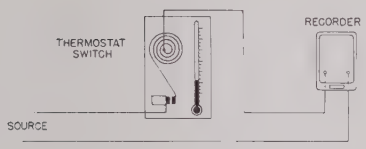
Application of Potential



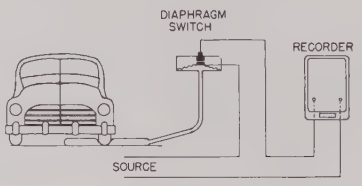
Rotary Motion



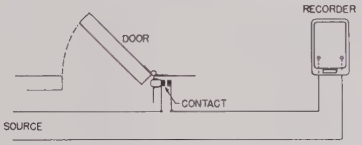
Reciprocating Motion



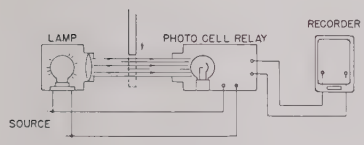
Temperature



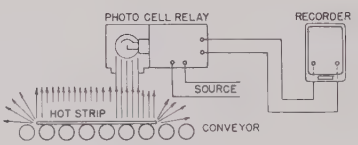
Pressure



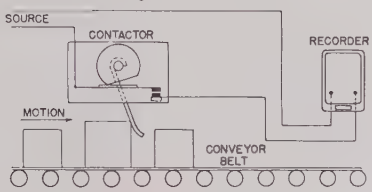
Position,
Weight or Force



Presence of an
Opaque Body



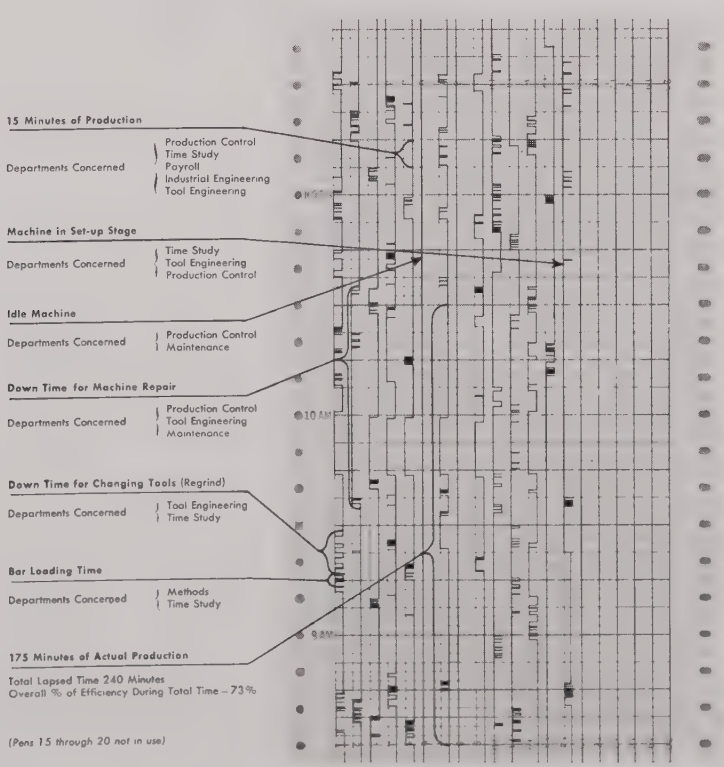
Presence of Light



Physical Contact

Adaptable to hundreds of research, production and maintenance uses, the "620" Esterline Angus Event Recorder with Tempen is an extremely versatile instrument. Sketches above show a few of the variety of ways in which its channels may be actuated.

The section of chart at right shows a typical record of screw-machine operation. The marginal notes reveal the type of information obtained from such a record. Channels 15 through 20 are not in use.



Excellence in graphic recording for over 50 years

SPECIFICATIONS / *"620" with Tempen*

principle of operation

Positive displacement of the stylus occurs when signal is present. Event styluses are displaced by electromagnets which can be rated for operation on various voltages and can be wired so each is electrically separate from the other (*separate circuits*); or can be wired with one common electrical terminal for all (*common return*). A third arrangement permits displacement of the styluses by the simple closing of a switch or contact (*switch type**).

A separate power supply is required as the heat source for styluses.

*A small step-down transformer, rated 120 or 240 volts, 50-60 cycles, is furnished with the switch-type arrangement to provide 24 volts to actuate electromagnets.

typical ratings for electromagnets which displace styluses (separate circuits or common return)

Rated Voltage*	Coil Style	Approximate Coil Milliamperes	Approximate Watts per Coil
DIRECT CURRENT			
12 Volts	F	120	1.4
28 Volts	B	40	1.2
50-60 CYCLES AC			
24 Volts	G	100	1.5
120 Volts	T	20	1.5

Other ratings from 2 Volts DC to 250 Volts DC and 6 Volts AC to 240 Volts AC are available.

*All electromagnets are guaranteed to operate at voltages 15% above or below rating.

stylus heating circuit

This circuit can be rated for operation from 120 volts, 50-60 cycles (25 VA), or from 12 volts AC or DC (2 amperes maximum). A rheostat is provided to adjust stylus heat thereby widening or narrowing recorded line.

cases

Portable, wall, flush and front switchboard cases are available. All but portable can also be furnished in a twin arrangement for mounting two "620" Event Recorders with Tempen. Flush cases come in choice of Esterline gray or charcoal. All others come in gray. Flush cases have 120 volt, 60 cycle fluorescent lighting, but incandescent lighting can be furnished, if desired.

chart drives

You can select from three chart drives: synchronous motor, Selsyn and phantom. Available chart speeds range from ¾ inches per hour to six inches per second.

charts

All charts are 80 feet long and six inches wide. They have rectilinear coordinates so arranged that the occurrence of events can be easily timed. At present, charts with time markings for operation at three inches per hour are available. Others will be offered later.

CHART NUMBER	For Recorders with Channels-in-use Numbering:
37010C	1 to 10
37020C	1 to 20
37040C	21 to 40 (for right-hand side of twin arrangement having 20 channels in left-hand side)

how to order (*specify*)

1. 10-channel or 20-channel Model.
2. Stylus Displacing Circuit (either separate circuits, common return or switch type).
3. Stylus Displacing Circuit Rating.
4. Stylus Heating Circuit Rating.
5. Case Style (if flush, choose color).
6. Chart Drive.
7. Chart Number.
8. Accessories and Attachments (writing door, glass corner in case cover, chart inspector, carrying case.)

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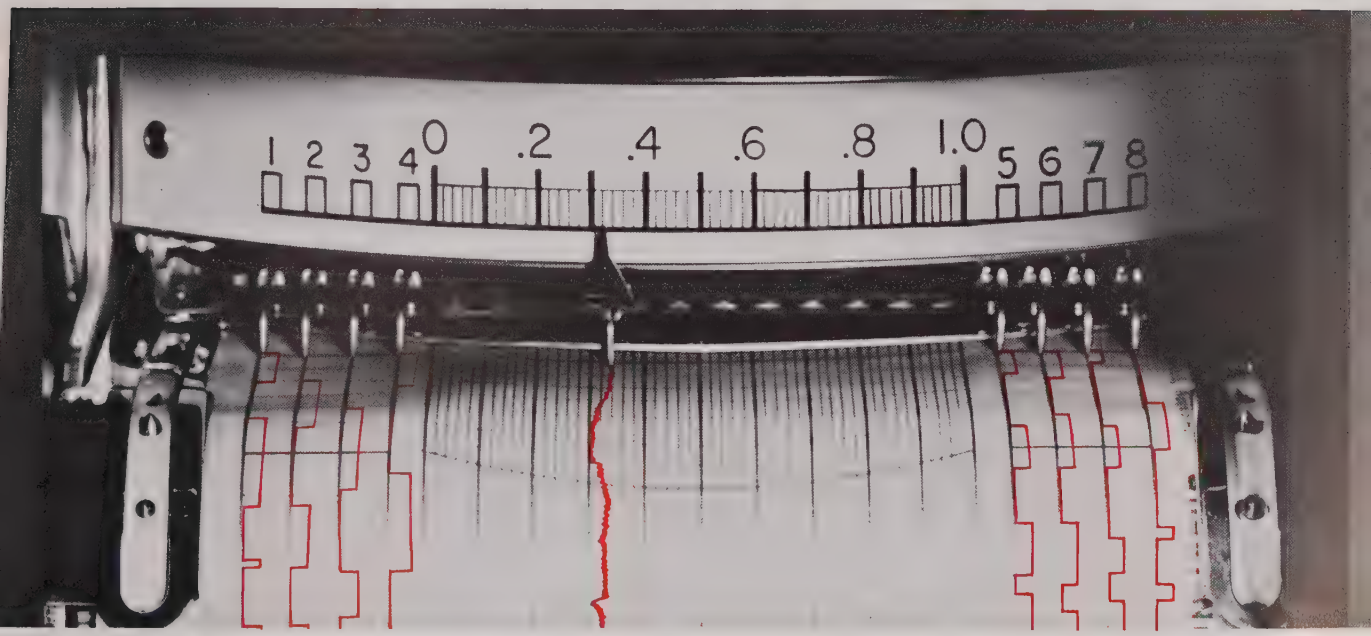
Excellence in graphic recording for over 50 years

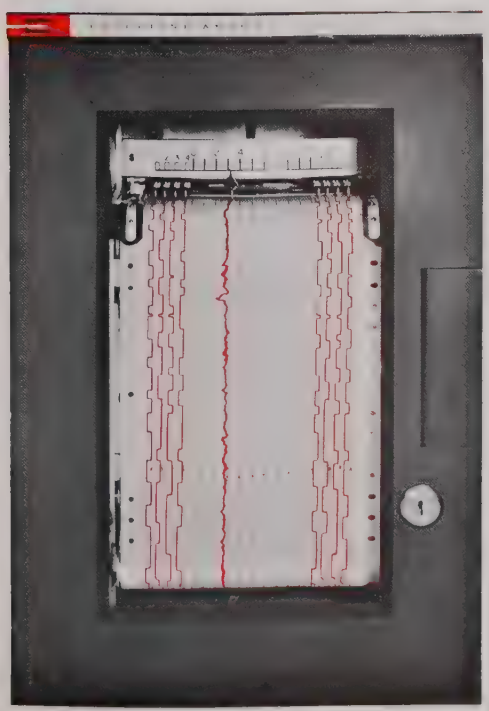
Form 6107 (10M)

Printed in U.S.A.

NEW!

from ESTERLINE ANGUS





"609" Analog-Event Recorder

What is it? The Analog-Event Recorder is an exclusive new Esterline Angus instrument which has the ability to simultaneously record analog data and up to eight channels of event information on a single 6″-wide strip chart. The analog information is recorded in the center 2¾″ of the chart, event information on the left and right sides.

What analog data can it record? Any data can be accommodated which is expressed as an AC or DC voltage, AC and/or DC current (including DC milliamperes or DC microamperes). In addition, AC watts, KVA, KVAR, pressure or vacuum can be recorded.

What's its capacity to gather event information? Eight channels of (on-off, yes-no) event information can be recorded by electromagnetically-operated pens. Four pens are mounted to write on the left side of the chart and four mounted to operate on the right side.

What are some of its recording uses? Wind speed and direction; substation bus voltage and breaker operation; rate of production (speed) and conveyor operation; light intensity and operation of photo cells; psychological and physiological conditions (using milliammeter or microammeter movement with event pens).

SEE OTHER SIDE FOR SPECIFICATIONS, ADDITIONAL INFORMATION

SPECIFICATIONS / *analog-event recorder*

voltage-type event pens (electrical ratings)

Rated Voltage*	Coil Style	Milli-amperes	Watts per Circuit	Ohms per Coil (DC)	Ohms in Series with Coil
Direct Current					
12 Volts	F	119	1.4	101	None
28 Volts	B	42	1.2	666	None
125 Volts	B	41	5.2	666	2400
50-60 Cycles AC					
24 Volts	G	103	1.5	61	None
120 Volts	T	20	1.5	1650	None

Other ratings from 2 Volts DC to 250 Volts DC and 6 Volts AC to 240 Volts AC are available.

*All electromagnets are guaranteed to operate at voltages 15% above or below rating.

NOTE: Switch-type event pens are available. A small, step-down transformer, rated 120 or 240 volts, 50-60 cycles, is furnished with the switch-type arrangement to provide 24 volts to actuate electromagnets.

analog measuring elements (ranges)

The following are representative ranges only. Many others are available. Write to us if the range you require is not listed. The instrument is extremely versatile and most recording requirements can be met.

0-1 Milliampere DC
0-5 Milliamperes DC
0-100 Volts DC
0-100 Amperes DC (0-100 MV)
0-50 Microamperes DC
0-5 Amperes AC } Dynamometer
0-150 Volts AC } Type

0-5 Amperes AC } Rectifier
0-100 Volts AC } Type
0-100—140 Volts AC
0-1000 Watts AC
0-1000 Vars AC
0-100 Pounds/Sq/Inch
0-1000 Feet/Minute

expanded ranges

Expanded AC or DC voltage ranges are offered. Approximately the upper ¼ of the range is expanded over the upper 80% of the channel width. The balance of the range is compressed into the lower 20% of the channel width, and is uncalibrated. An electrical and mechanical zero is a feature of these expanded ranges.

cases

Portable, wall, flush and front switchboard single cases are available and all but portable are also furnished in twin mounting. Flush cases come in choice of Esterline gray or charcoal. All others come in gray. Flush cases have 120 volt, 60 cycle fluorescent lighting, but incandescent lighting can be furnished if desired.

chart drives

Three general classes are available: hand-wound spring, motor-wound spring, synchronous. Each type provides chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds of ¾, 1½ and 3 inches per second are obtained with external motor attachments.

charts

Charts are 6 inches wide and have positions for eight event pens. Listed below are several styles which are most popular. Others are available at standard prices. Many special designs can also be supplied. Write, giving details.

	Chart Number	Range	Ruling
Uniform Rulings	33010	0-1	10-50
	33018	0-5	10-50
	33029	0-30	12-60
	33039	0-100	10-50
	33043	0-150	15-30
	33400	0.5-0-0.5	10-50
	33424	100-0-100	10-50
Uniform Rulings (Expanded Scale)	33500	0-100—140	10-50
Quadratic Rulings	33612	0-5	Q10-50
	33629	0-100	Q10-50
	33633	0-150	Q15-75

how to order (specify)

1. Event Pens (electrical rating).
2. Analog Measuring Element (range).
3. Case Style (if flush, choose color).
4. Chart Drive.
5. Chart Number (or submit details of range of analog channel and chart speed required).
6. Accessories and Attachments (writing door, glass corner in case cover, chart inspector, carrying case).
7. Supplies (charts, extra pen elements for analog and event channels, pen point cleaners, writing fluid.)

ESTERLINE ANGUS INSTRUMENT COMPANY, INC.
BOX 596 • INDIANAPOLIS 6, INDIANA
Excellence in graphic recording for over 50 years

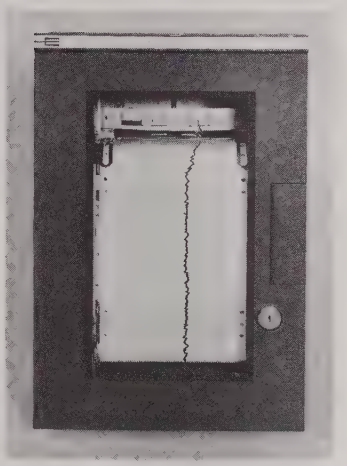
Form AE-261A (10M)

Printed in U.S.A.

ESTERLINE ANGUS

Esterline Angus Instrument Co., Inc., Box 596, Indianapolis 6, Ind., U.S.A.

EXPANDED SCALE RECORDING VOLTMETERS



Recording voltmeters with expanded scales are now available to fit the various channel widths of Esterline Angus instruments. These new instruments can be obtained for either AC or DC measurements. At present an AC range of 0-100——140 volts is available to accommodate utility applications and for checking power circuits. For other ranges consult the Esterline Angus Application Engineering Section to work out the details.

The instrument uses a permanent-magnet moving-coil measuring system and is arranged so that approximately the upper one fourth of the voltage range is expanded to fill the upper 80% of the chart span. The expanded portion is linear and uniformly ruled charts are used. The balance of the voltage range is compressed into the lower 20% of the chart span and is non-calibrated and non-linear. An electrical and mechanical zero to permit checking and adjustment of the instrument is a feature. The principle of operation and performance data are given in later paragraphs.

FEATURES

1. Increased readability of voltage records over other methods.
2. Mechanical and electrical zero to permit checking instrument and to indicate a no-voltage condition.
3. Readable deflection for short voltage transients.
4. Uniformly ruled charts for easy interpretation of records.
5. A noticable pen deflection for small voltage changes.

PRINCIPLE OF OPERATION

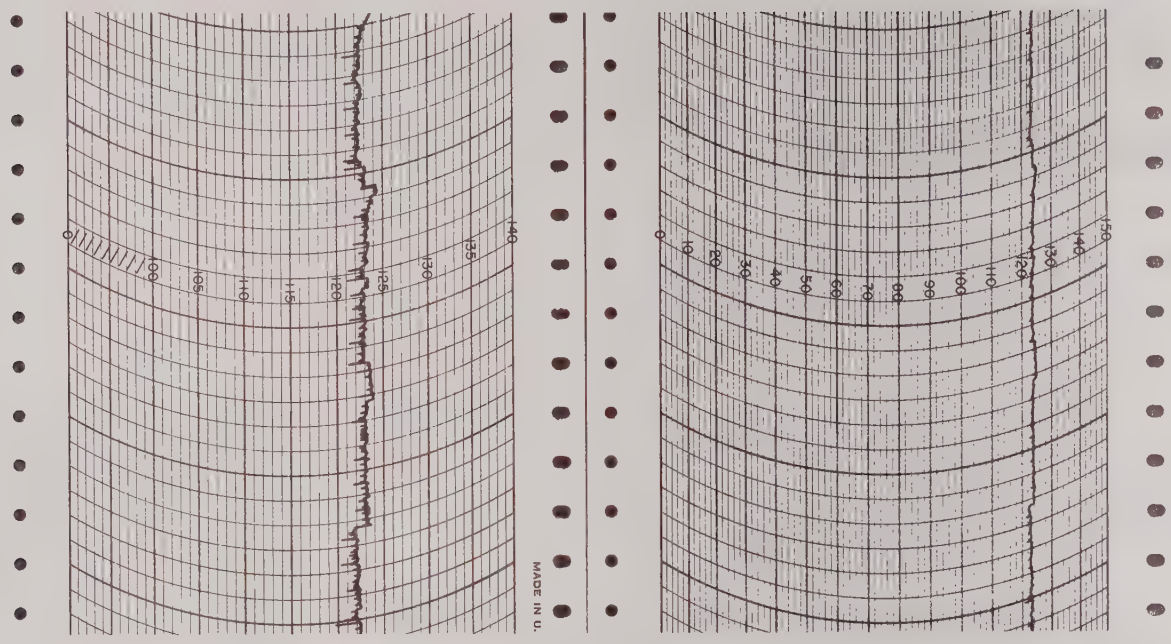
Following is a description of the principle of operation:

Scale expansion is accomplished by applying the difference between the input voltage and the constant voltage developed across a solid-state semiconductor, the zener diode, to the measuring circuit. This action takes place over the upper 80% of the chart span, while below that point, good conduction of the semiconductor diode has not taken place and the measuring circuit current is limited, thereby accomplishing the compression of the lower portion of the voltage range. Suitable calibrating resistors allow a wide variety of voltage ranges to be accommodated.

AC voltmeters utilize a rectifier and filter system to drive the expansion circuitry. Although these AC voltmeters are of the rectifier type, and are, therefore, calibrated in terms of RMS value for a sine wave input, compensation has been added to minimize the effects of typical wave form distortion and thereby enable the instrument to indicate RMS values more accurately than true average reading instruments for this type of distortion.

High reliability solid-state components are used throughout in this device including a precision temperature compensated zener reference diode as the heart of the expansion circuitry.

EXPANDED SCALE RECORDING VOLTMETERS (CONT.)



The chart sections above compare recordings of a voltage as drawn simultaneously by an expanded scale instrument (left) and a conventional instrument (right).

ESSENTIAL PERFORMANCE DATA

RANGE: 0-100——140 volts AC

Other AC and DC voltage ranges are possible. (Consult Esterline Angus Application Engineering Section)

Note: Recording of DC voltages having an AC ripple content in excess of 2% requires special consideration.

ACCURACY: Plus or minus 1% of the full scale value on DC or AC (sine wave).

RESPONSE:

A. Approximately 1/2 second for full recording of the voltage change.

B. A readable deflection can be obtained for much shorter voltage transients. For example, a deflection of approximately 1/4 inch can be obtained on the 0-100——140 AC range for a transient between 100 and 140 volts of approximately 2 volts amplitude and 65 milliseconds duration.

FREQUENCY: The AC ranges can be used on any frequency from 50 to 200 cycles. Specific calibrations for higher frequencies (such as 400 cycles) can be furnished at no extra charge. It will be necessary to consult the Esterline Angus Application Engineering Section on these applications.

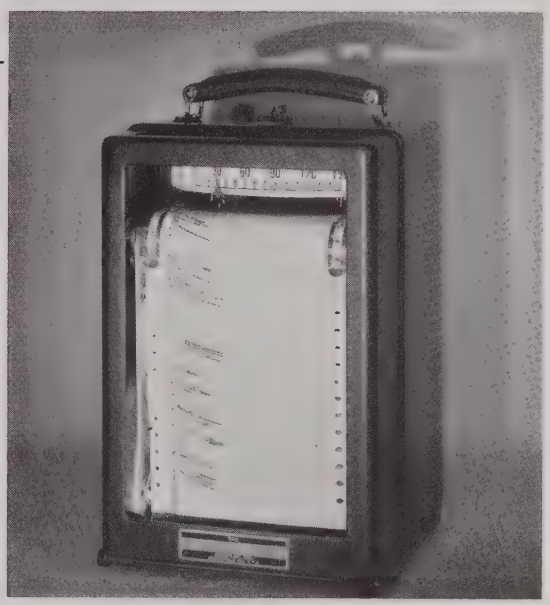
BURDEN: The burden of the measuring circuit depends upon the range specified. In general, the maximum current burden will be approximately 50 milliamperes for DC ranges and 150 milliamperes for AC ranges.

ESTERLINE ANGUS INSTRUMENT COMPANY, INC.

P. O. Box 596 Indianapolis 6, Indiana

Form 6106 2,5M 761 Printed in U.S.A.

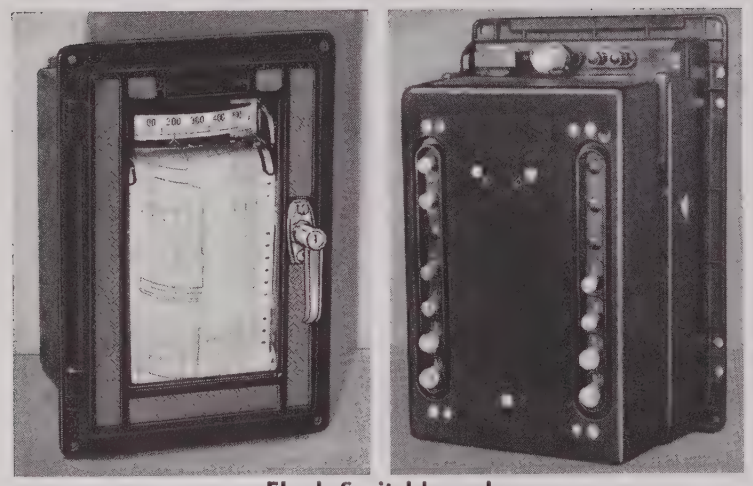
ESTERLINE-ANGUS
Recording Instrument
Cases



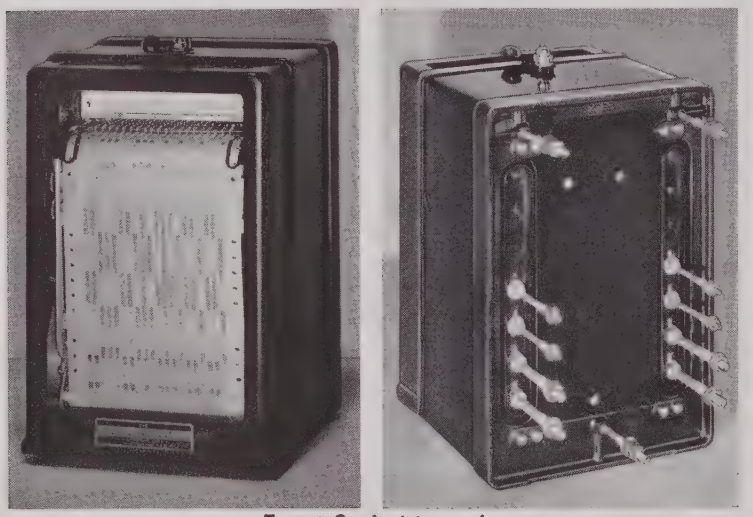
EACH CASE consists of two parts, the case proper and the case cover or door. Both are high strength aluminum alloy die castings. All cases are finished in black baked enamel. Covers or doors all close tightly against rubber gaskets to keep out dust and dirt. Glass is set in sealing compound and held in place with metal clips. Each case has mounting bosses cast in it for locating the measuring element and chart drive in accurate relation to each other. Chart drives and measuring elements can be interchanged from one style case to another without impairing the accuracy of the instrument.

Front and rear views of a portable instrument showing the cover latch, handle, terminals and attached multiplier box.

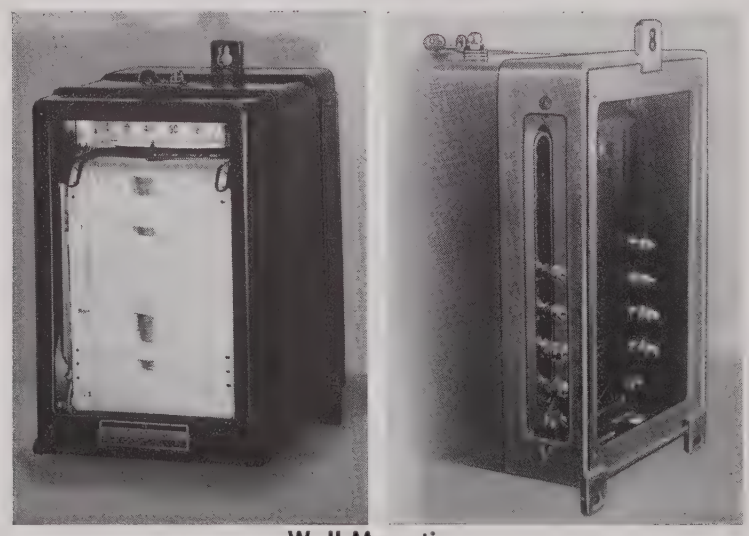
SINGLE CASES



Flush Switchboard



Front Switchboard



Wall Mounting

Portable Case

The most popular of the single case styles is the portable, illustrated on the preceding page. This case is equipped with a rubber handle and its multiplier box, when required, is mounted on the back of the case. The cover is arranged so that it will open when the meter is sitting on a flat surface and it can be unhooked and laid aside when the meter is being serviced. It is fastened with an eccentric latch that can be padlocked or sealed. The bottom of the case has four holes drilled and tapped for No. 10-24 screws, so it can be fastened securely to a shelf or table. Terminals of portable meters are threaded for binding post studs or screws and are tapered to take the plug-in type of leads, usually furnished. Five foot leads are supplied with portable meters, except for DC milliammeters, which are furnished with binding posts. The current circuits of DC and AC-DC wattmeters and DC ammeters must use calibrated leads. Binding posts cannot be substituted in these circuits.

Permanently Mounted Cases

Single case styles, designed for permanent mounting are: (left—top to bottom) Flush switchboard, Front Switchboard and Wall or surface mounting. These cases are also available as twins, illustrated at the right in the same sequence. In ordering any of the permanently mounted cases, the material and thickness of the panel must be stated, so the correct length of mounting studs can be furnished and calibration compensated, if necessary. Twin meters are used to conserve panel space and reduce cost. They are usually equipped with a power chart drive mounted in the right-hand side and a slave or phantom drive in the left.

Flush Switchboard Case

In these cases the body and the mounting flange are die-cast in a single unit. The doors are hinged at the left and closed by means of a lever-type latch containing a lock. Fluorescent lighting is provided to illuminate the scale

and a portion of the record. The ballast and starter are mounted on top of the case body as shown in the rear view of the single case. Incandescent lighting can be furnished where a 120 volt, 60 cycle source is not available. The twin case is 19 inches wide over-all and can be mounted on a 20-inch panel. Since the portion extending back of the flange is only 17⅝ inches wide, this case can be fitted to a standard 19-inch relay rack, although special drilling of the mounting channels or case may be required.

Front Switchboard Case

Front switchboard cases are intended for projection mounting on panels with studs for rear connection. A mounting ring is added to the case body and the three mounting studs are independent of those used for electrical connections.

Single instruments can be mounted side by side on 8¾-inch centers. Case covers are the same as previously described for portable cases and can be locked in the same manner. Multiplier boxes, if needed, are mounted separately on the rear of the panel. No leads are furnished with these case styles unless they are part of the calibrated measuring circuit, as with DC ammeters and DC and AC-DC wattmeters.

Wall Mounting Case

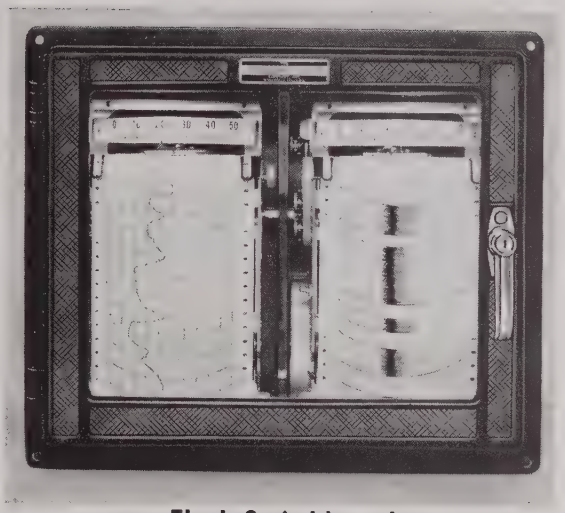
Wall cases are designed for mounting on any flat vertical surface. A mounting and wiring compartment is attached to the back of the case body. This compartment is fitted with removable steel covers so the connections are not exposed in operation. Two 1-inch threaded holes in the bottom of the compartment are fitted with chase bushings. No leads are furnished with single cases except for the current circuits of DC and AC-DC wattmeters and DC ammeters, and separate circuit operation recorders having more than 10 pens. With twin cases, three-foot leads are furnished, extending through the bushings, except for the aforementioned DC meters, where five-foot calibrated leads are supplied.

Overall Dimensions and Weights

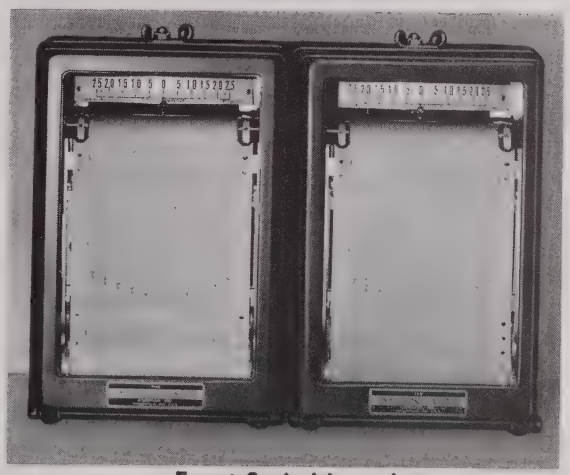
Type of Case	Width Inches	Height Inches	Depth Inches	Approx. Weight Complete Meter	
				Net Weight	Shipping Weight
Portable	8⅜	14½	*8¾	34	70
Flush	10¾	16	*8½	38	75
Flush Twin	19	16	*8½	60	110
Front Swbd.	8¾	14	9¼	32	65
Fr. Swbd. Twin	17½	14	9¼	60	90
Wall	8⅝	15	10⅝	38	72
Wall Twin	17⅜	15⅜	10⅝	65	95

*Add 2¾ inches to depth for meters with standard attached multipliers. For external motor chart drive on front switchboard meters, allow 4⅜ inches in the width on the right hand side when looking at front of meter. For external motor chart drive on flush meters add 3⅛ inches to the width on the right hand side.

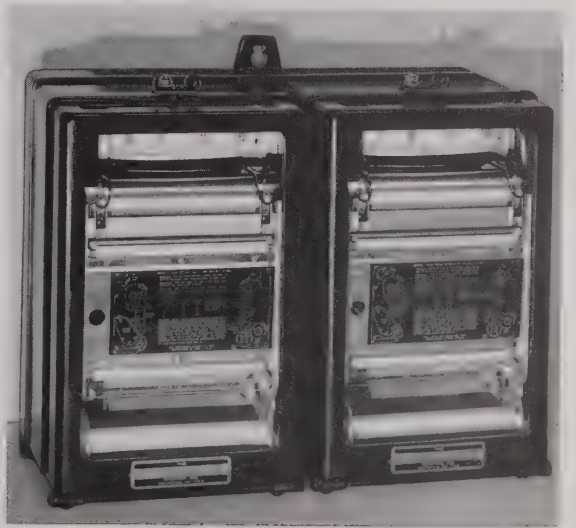
TWIN CASES



Flush Switchboard



Front Switchboard



Wall Mounting

Additional Case Features

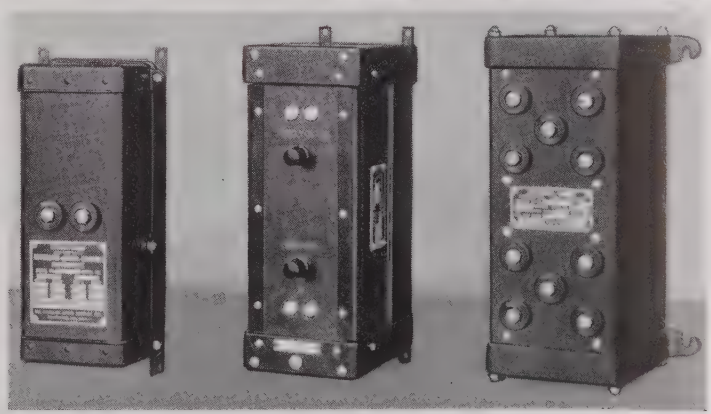
←— **Writing Door**—All case styles, except twin flush switchboard, can be equipped with a writing door as illustrated at the left. The flat instruction plate for the chart drive forms the writing surface behind the chart so that notes can be written on the record without opening the case cover.

—→ **Glass Corner**—Where the recorder is installed below eye level and the usual solid corner of the case cover obscures the view of the scale and pen, the glass corner, shown at the right, is a convenient feature.

←— **Binding Posts**—All terminal holes in E-A meters are tapered and threaded to take either the tapered plugs usually furnished on leads, or binding posts (left). Binding posts can be used instead of leads on portable meters where the leads *are not* a calibrated part of the measuring circuit.

—→ **Chart Feeding Slot**—It is sometimes convenient to let the chart feed out of the bottom of the case so it can be torn off after each shift or test. This feature (right) can be obtained at will on portable, front switchboard and wall cases simply by removing the rubber gasket at the bottom of the cover. As a special feature, flush cases can also be modified so the chart can be fed out in front of the panel.

Padlock or Seal—Portable, wall and front switchboard case styles may be locked against tampering with a padlock or can be sealed with the usual meter seal.



Multiplier Boxes—Relative sizes of the standard and deep style and the large separate multiplier boxes are shown, left to right. Standard and deep style boxes are fastened to the back of portable and flush meters. The large box is always separate. Both portable and permanently mounted styles are available.

THE ESTERLINE-ANGUS COMPANY, INC.

Pioneers in the Manufacture of Graphic Instruments

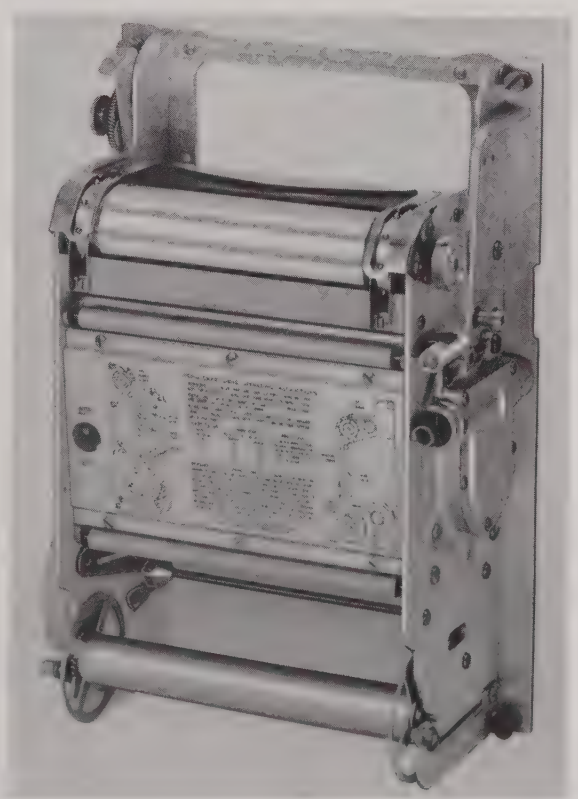
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

Catalog Section 15
Printed in U. S. A., 5M

Product Representatives
in Most Principal Citie

ESTERLINE-ANGUS CHART DRIVES

Hand-Wound Spring
Motor-Wound Spring
Synchronous Motor
Selsyn
Phantom
External Motor



The chart driving mechanism of a recording instrument not only must keep correct time of day but also must provide the energy to unwind the chart paper from the supply roll, propel it through the drive and rewind it. It must have adequate power to perform these functions under conditions of high temperature and humidity in one season or location and low temperature and humidity in another. E-A is proud to claim the most complete line of chart drives made. Each drive is interchangeable with any other, thus providing a maximum of flexibility.

E-A chart drives are designed and built completely in our own plant by men who have devoted the results of their entire experience to the production of chart driving devices for graphic instruments. Their attention is centered on just this one problem and the results speak for themselves, in terms of reliability, low maintenance and long life.

Esterline-Angus Chart Drives

Chart drives may be divided roughly into spring, electrical and mechanical (or phantom) drives. The usefulness of the complete meter depends in no small degree on selecting the proper chart drive motive power and chart speeds. The variety of driving means and available chart speeds make it possible to choose a chart drive that will satisfy the most variable operating requirements.

INTERNAL CHART DRIVES (Three pairs of change gears for ¾, 1½, 3, 6 and 12 inch chart speeds are included with each drive.)		STANDARD CHART SPEEDS			INTERNAL MOTORS		ELECTRIC SHIFT COILS			Details on Page
No.	TYPE	Inches Per Hour	Inches Per Minute	Inches Per Second	AC Volts	Frequency	DC Volts	AC Volts	Frequency	
1	Hand-wound Spring, Hour Feeds Only	¾, 1½, 3, 6, 12	.....	.....	.....	.....	.....	.....	.....	4
2	Hand-wound Spring, Hour and Minute Feeds	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	.....	.....	.....	.....	.....	.....	4
2A	Hand-wound Spring, Hour and Minute Feeds with Electric Shift	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	.....	.....	.....	6-48	4-80.....25 6-120.....50, 60		4
4	Synchronous Motor, Hour and Minute Feeds	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	.....	120, 240[a]	25, 50, 60	.....	.....	.....	6
4A	Synchronous Motor, Hour and Minute Feeds with Electric Shift	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	.....	120, 240[b]	25, 50, 60	6, 12, 24, 48 125, 250	120, 240	25, 50, 60	6
6X	Phantom, Spring reroll, without clutches	No power unit. One revolution of coupling shaft moves ¾, 1½, 3, 6 or 12 inches of paper under pen point with corresponding gears in place. Furnished complete with coupling.			.....	.....	.....	.....	.....	8
6C	Phantom, Spring reroll, with drag clutch				.....	.....	.....	.....	.....	8
6CC	Phantom, Spring reroll, with drag and back-up clutches				.....	.....	.....	.....	.....	8
6EX	Phantom, Electric reroll, without clutches				120, 240[a]	25, 50, 60	.....	.....	.....	8
6EC	Phantom, Electric reroll, with drag clutch				120, 240[a]	25, 50, 60	.....	.....	.....	8
6ECC	Phantom, Electric reroll, with drag and back-up clutches				120, 240[a]	25, 50, 60	.....	.....	.....	8
51	Motor-wound Spring, Hour Feeds Only	¾, 1½, 3, 6, 12	.....	.....	120, 240[b]	25, 50, 60	.....	.....	.....	4
52	Motor-wound Spring, Hour and Minute Feeds	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	.....	120, 240[b]	25, 50, 60	.....	.....	.....	4
52A	Motor-wound Spring, Hour and Minute Feeds with Electric Shift	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	.....	120, 240[b]	25, 50, 60	6-48	4-80.....25 6-120.....50, 60		4
60	Selsyn	¼, ½ or 1 inch per revolution of Selsyn with ¾, 1½ or 3 inch gears in place.			120	60	.....	.....	.....	7

EXTERNAL MOTOR ATTACHMENTS, Page 9

TYPE		Chart Speeds Inches per Second	Motor Rating		
			DC Volts	AC Volts	AC Frequency
N	Second Feed non-reset	¾, 1½, 3[c]	12, 24, 48, 125, 250	120	50, 60
R	Second Feed, with Time Reset	¾, 1½, 3[c]	24, 48, 125, 250	120	50, 60

All drives except 6CC, 6ECC and 60 can be coupled to other drives or an external motor on either the right or left side. The 6CC and 6ECC drives can be coupled only on the right side; the 60 drive can be coupled only on the left side.

[a] Electric chart drives are normally furnished for one voltage only. At additional cost, 120/240 volt, 50 or 60 cycle chart drives are available.

[b] Single voltage ratings only are supplied.

[c] Speeds above 3 inches per second are mechanically possible but not recommended. When combined with No. 51, 52 and 52A internal drives, use ¾ inch per second only. If power to these three types of internal drives should fail, they will reroll only 18 inches of chart.

Dielectric Tests—Electrical features of all internal chart drives withstand 1500 volts, 60 cycles for one minute. External motors, 12-48 volts DC are tested at 500 volts, 60 cycles and higher voltage ratings, both AC and DC at 900 volts, 60 cycles.

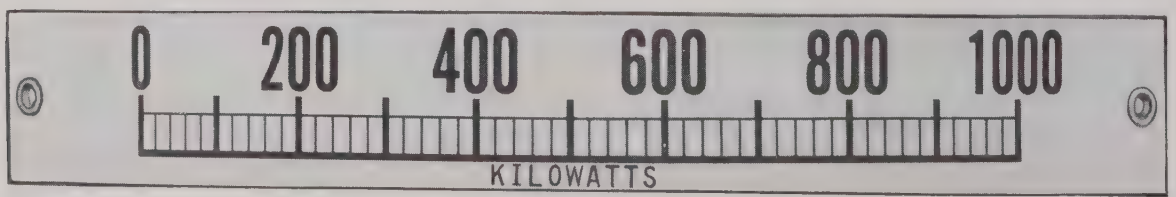


FIG. 1—*The scaleplate is carried between the sideplates of the chart drive. It snaps in place, is removable without the use of tools and swings up out of the way to give access to the writing system*

FROM their inception, E-A graphic instruments have provided chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. A full set of change gears to provide all five hour speeds is supplied with each chart drive. The change from one hour speed to another is made manually by changing gears on the side of the drive. Changing from inches per hour to inches per minute can be manual or electric.

Over the years, the methods of providing this variety of chart speeds have grown from the original, hand-wound spring drive to the present list of standard drives shown on the opposite page. All drives are interchangeable in all Model AW cases. A spring drive may be substituted for a synchronous or phantom drive at will. The interchangeable assembly principle is carried within the chart drive also. The reroll gear train, springs, escapement, and drive roll are easily replaceable assemblies. All gears have generated teeth; no stamped or milled gears are used. Spare change gears are carried in a handy clip at the top of the drive. Supply roll arbor and reroll arbor snap in place with a slight push. These features make E-A chart drives the most rugged and reliable and the most convenient for the user.

Selection of Chart Drive

In selecting the proper chart drive to use in a recording instrument, it is necessary to consider what quantities are to be measured and where. Will they vary rapidly or be relatively constant? Must the chart drive operate independently of any electrical power source? Must it operate unattended for two weeks, three, or only one week? In the following pages, these points are considered to assist in making the proper selection.

High chart speeds for fault recording, transient analysis and the study of other rapidly varying quantities are provided by an external motor drive since more power is required than can be delivered reliably by an internal chart driving source.

FIG. 4—*Wall mounting recorder with DC, Type R external motor attachment. The rheostat, used only with DC motors, is integrally mounted on portable, front switchboard and wall recorders. It is separately mounted for flush recorders*

These external drives can be used on any Model AW recorder with one of the following chart drives:

No. 1, 2, 2A, 4*, 4A*, 6C, 6EC*, 51*, 52*, 52A*

(a minor modification of the drive may be necessary if it was shipped prior to 1951)

*If power to these drives should fail, they will reroll only 18 inches of chart.

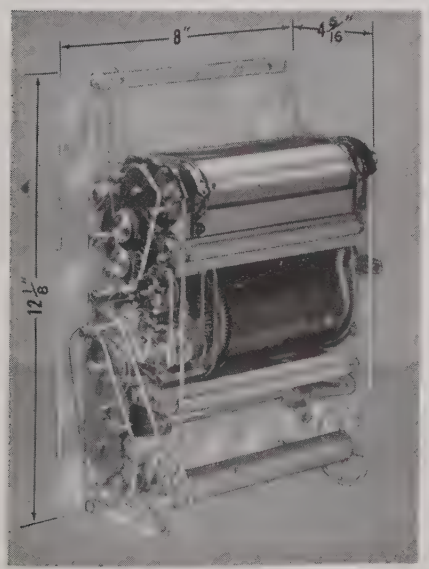
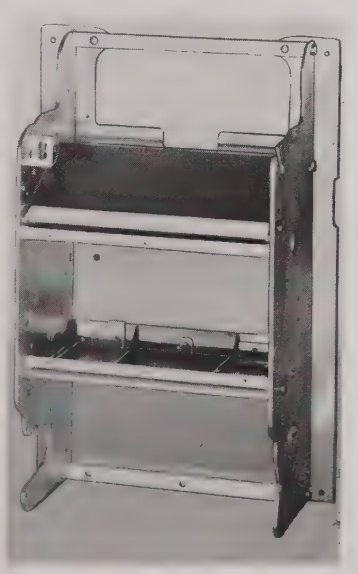


FIG. 2—*Plastic-housed model (left) of a hand-wound spring drive shows the large number of parts mounted within the box frame common to all drives. Overall dimensions of the drive are also shown*

FIG. 3 (*right*)—*Each chart drive is mounted on a rigid aluminum box type frame which has the same dimensions for each drive. This construction maintains the accurate alignment of all parts and resists damage to the chart drive even though the recorder is subjected to rough treatment*



Spring Powered Chart Drives

No.	TYPE	Standard Chart Speeds		Speed Change Mechanism	RECOMMENDATIONS
		Inches Per Hour	Inches Per Minute		
1	Hand-wound Spring, Hour Feed	¾, 1½, 3, 6, 12	.....	.....	Use where chart drive must be entirely independent of any power supply, and where rapid fluctuations of the measured quantity do not occur.
2	Hand-wound Spring, Hour and Minute Feed	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	Manual	Use where chart drive must be entirely independent of any power supply, and where rapid fluctuations of the measured quantity are to be studied.
2A	Hand-wound Spring, Hour and Minute Feed, with Electric Shift	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	Manual or Electric	Use where normal chart drive operation must be entirely independent of any AC power supply, where rapid fluctuations of the measured quantity occur, and where change from hour to minute feed must be made automatically or from a remote point.
51*	Motor-wound Spring, Hour Feed	¾, 1½, 3, 6, 12	.....	.....	Use where AC is available, where record must be independent of power supply interruption, and where rapid fluctuations of the measured quantity do not occur.
52*	Motor-wound Spring, Hour and Minute Feed	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	Manual	Use where AC is available, where record must be independent of power supply interruption, and where rapid fluctuations of the measured quantity are to be studied.
52A*	Motor-wound Spring, Hour and Minute Feed with Electric Shift	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	Manual or Electric	Use where AC is available, where record must be independent of power supply interruption, where rapid fluctuations of the measured quantity occur, and where change from hour to minute feed must be made automatically or from a remote point.

All of these chart drives are equipped with take-over clutch and have through shaft for coupling to each other, to a phantom, to an external motor attachment or other external driving source. If the external driving source can reverse, the internal drive must be equipped with a back-up clutch, and coupling must be on the right-hand side.
*If power to these drives should fail, they will reroll only 18 inches of chart.

SPRING CHART DRIVES are of two types, hand wound and motor wound. Both types are powered by springs and timed by a temperature-compensated escapement. In accuracy of timing, both drives are identical, so the selection of the type best suited to a particular application depends on the availability of a source of power, continuity of service, ease of attending the meter, etc.

Escapements are made in two styles, hour-feed, and hour-and-minute feed. An hour-feed drive may be converted to hour-and-minute feed simply by changing the escapement unit. Anyone can make the change, using only a screw driver, by following the simple procedure outlined in the instruction book furnished with each recorder.

Timing at hour feed is regulated by a temperature-compensated balance wheel with jeweled bearings. At minute feeds, the timing is controlled by a fly-ball governor, also jewel mounted, which is included in the minute feed escapement assembly. Means for regulation are provided on both hour and minute feed escapements but adjustments are seldom necessary. Escapements are shipped pretimed and it is a

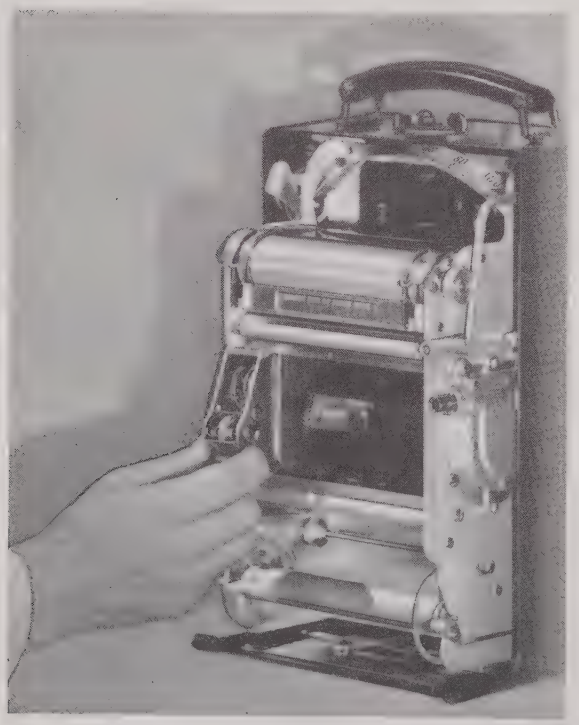


FIG. 5—*The escapement unit is removable, after letting down the springs. With a spare escapement in stock, spring chart drives can be kept in operation while an escapement is sent in for repair*

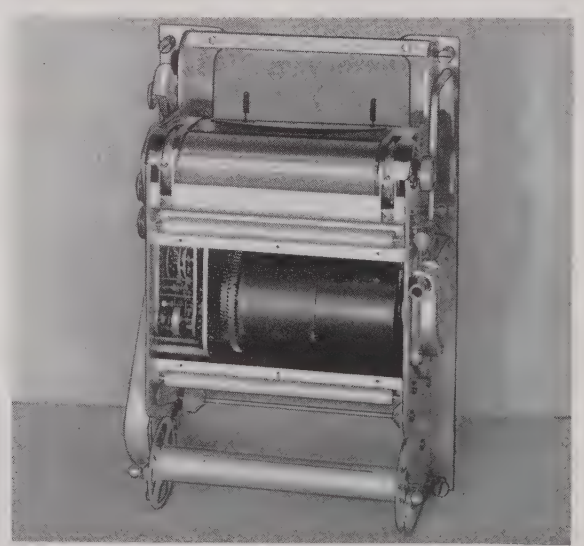


FIG. 6—*The gear clip storing extra change gears can be seen at the upper left and the clock winding crank at the right. The springs are housed in pairs and all four springs unwind together*

simple matter to exchange escapements in these spring chart drives and avoid an extensive timing test.

At any of the five standard hour speeds, the timing accuracy is of the order of 5 minutes per week or 0.05%. At any of the minute speeds, the timing accuracy is about one second per minute or 1⅔%.

In the hand-wound drives, four springs connected in series propel the chart through the drive and reroll it after the record is made. They are housed in pairs, Fig. 6, and all are wound from the front of the drive at one time by a crank. About 110 turns of the crank are required to wind the four springs completely. After 8 days of continuous operation, at any hour feed, about 65 turns are required to restore full power to the springs. In operation, a regular schedule should be set up so the springs are wound once a week. At any of the minute feeds, one winding of the springs lasts about 3½ hours.

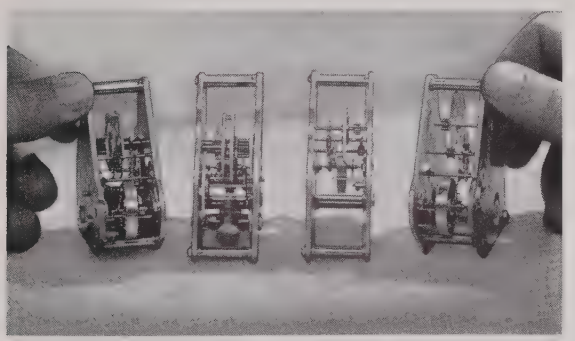


FIG. 7—*At the left are two views of the hour and minute feed escapement and, right, two views of the hour feed escapement unit. A simple change of escapements is required to change a drive from hour feed only to hour-and-minute feed*

In motor-wound spring chart drives a smaller helical spring is wound by a motor at regular intervals. A second motor winds a small reroll spring. Both motors are energized by a cam-operated switch for approximately 20 minutes in each hour. If the power source is interrupted, the chart drive will continue in operation for at least five hours in any hour feed. When power is restored, the springs will be rewound at the next succeeding closing of the switch. If the power remains off long enough for the storage springs to run down, the motors may not restart when power is restored. A start button is provided to energize the motors and wind the springs, even though the internal switch is open.

FIG. 8—*In the middle section of the motor-wound spring drive, the escapement unit is visible at the extreme left. Next, proceeding toward the right, is the reroll motor, the switch to energize the motors, and the motor which winds the mainspring*

The change from hour to minute feed, in either hand-or motor-wound spring drives, can be made manually by simply moving the control lever on the side of the chart drive. Electric shift mechanisms are also available so the change can be effected from a remote point.

A hand-wound spring drive should be used where the chart movement must be independent of any power source and where it is possible to wind the springs once a week. The motor-wound spring drive can be used where AC is available, either regulated or unregulated frequency, and where the record must be independent of power interruptions to the drive. This drive has the advantage that the meter need be serviced only when the chart needs changing. In continuous operation, the meter needs servicing only every 2 weeks at 3 inches per hour, 4 weeks at 1½ inches per hour.

Where practically constant quantities are being recorded, hour feed drives Nos. 1 and 51 can be used. However, if rapid fluctuations are likely to be encountered, the minute feed drives Nos. 2, 2A or 52 and 52A should be used to open up the record for more thorough study.

Electric Shift Coils—2A and 52A Drives

Rating of Shift Coil†	VA	Watts	Amperes
6 Volts DC	.....	1.3	0.21
12 Volts DC	.....	1.3	0.11
24 Volts DC	.....	1.4	0.06
48 Volts DC	.....	1.4	0.03
24 Volts, 25 Cycles	1.9	1.4	0.08
24 Volts, 50-60 Cycles	2.4	1.3	0.10
120 Volts, 50-60 Cycles	2.4	1.4	0.02

†Both AC and DC Shift Coils are designed for continuous operation.

Motors—51, 52, 52A Drives

Motor Rating	VA*	Watts*	Amperes*
120 Volts, 60 Cycles	15	6	0.13
240 Volts, 60 Cycles	15	6	0.07
120 Volts, 50 Cycles	15	6	0.13
240 Volts, 50 Cycles	15	6	0.07
120 Volts, 25 Cycles	9	4	0.08
240 Volts, 25 Cycles	9	4	0.04

*Total load of chart drive is twice these figures.

Synchronous Chart Drives

No.	TYPE	Standard Chart Speeds		Speed Change Mechanism	RECOMMENDATIONS
		Inches Per Hour	Inches Per Minute		
4	**Synchronous, Hour and Minute Feed**	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	Manual	Use where frequency regulated AC is available, where it is not necessary for record to continue during power supply interruption, and where rapid fluctuations of the measured quantity occur.
4A	**Synchronous, Hour and Minute Feed with Electric Shift**	¾, 1½, 3, 6, 12	¾, 1½, 3, 6, 12	Manual or Electric	Use where frequency regulated AC is available, where it is not necessary for record to continue during power supply interruptions, where rapid fluctuations of the measured quantity occur, and where a change from hour to minute feed must be made automatically or from a remote point.

These drives are equipped with take-over clutch and through shaft for coupling to a phantom, external motor attachment or other external driving source. They should not be coupled to each other. If the external driving source can reverse, the internal drive must be equipped with a back-up clutch, and coupling must be on the right-hand side.

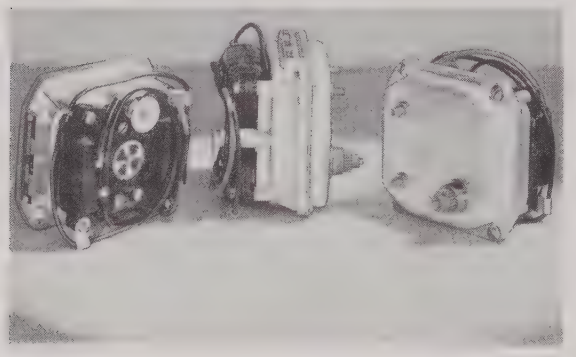


FIG. 9—*The synchronous timing motor (above) has the speed change mechanism for hour and minute speeds incorporated in its gear train. The output shaft runs at 24 RPH or 24 RPM*

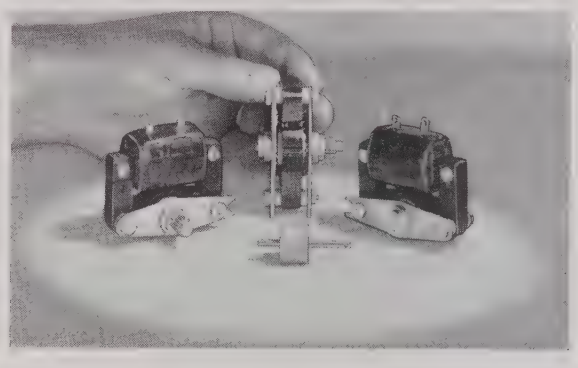


FIG. 11—*The reroll motor (above) is a stalled induction motor which, through a gear train and small storage spring, winds the chart on the reroll as rapidly as it is fed through by the timing motor*

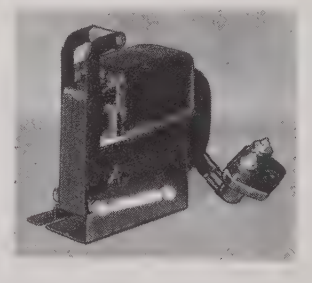


FIG. 10—*The electric shift mechanism (right) shifts gears in the train inside the motor to change the chart speed from inches per hour to inches per minute*

THE SYNCHRONOUS motor chart drive is used where a source of frequency-regulated AC is available and where it is not necessary that the record continue during power supply interruptions. The chart is propelled by a self-starting synchronous motor which is permanently lubricated by means of an oil reservoir and felt wicks. Four pole motors are used on 50 and 60 cycles, running 1500 and 1800 RPM, respectively, and a 2-pole, 1500 RPM motor on 25 cycles.

The motor housing is gasketed and sealed, thus eliminating the necessity of periodic oiling. The reroll mechanism is powered by a separate stalled in-

Motor and Electric Shift Coil Data—Types 4 and 4A Chart Drives

Rating	Combined Load of Timing and Reroll Motors			Reroll Motor Only			Electric Shift Coils*		
	VA	Watts	Amperes	VA	Watts	Amperes	VA	Watts	Amperes
6 Volts DC	.....	.....	.....	.....	.....	.....	.....	10	1.7
12 Volts DC	.....	.....	.....	.....	.....	.....	.....	10	0.8
24 Volts DC	.....	.....	.....	.....	.....	.....	.....	10	0.4
48 Volts DC	.....	.....	.....	.....	.....	.....	.....	10	0.2
125 Volts DC	.....	.....	.....	.....	.....	.....	.....	10	0.08
250 Volts DC	.....	.....	.....	.....	.....	.....	.....	10	0.04
120 Volts, 60 Cycles	23	10.5	0.19	15	6	0 13	13	5	0.11
240 Volts, 60 Cycles	23	10.5	0.09	15	6	0.07	13	5	0.06
120 Volts, 50 Cycles	26	13	0.21	15	6	0.13	16	6	0.14
240 Volts, 50 Cycles	26	13	0.11	15	6	0.07	16	6	0.07
120 Volts, 25 Cycles	17	9.5	0.14	9	4	0.08	13	6	0.11
240 Volts, 25 Cycles	17	9.5	0.07	9	4	0.04	13	6	0.06

*All AC shift coils are designed for continuous operation. DC shift coils should be energized intermittently, not more than 5 minutes on, followed by an equal off period.

duction motor which automatically adjusts its take-up rate to match the chart speed in use. Both motors are started and stopped by a single switch.

Standard drives have a single voltage and frequency rating of 120 or 240 volts, 25, 50 or 60 cycles. Double rated 120/240 volt motors are available for 50 or 60 cycles. When supplied in portable meters, synchronous drives are furnished with a 10-foot duplex lead having spade terminals on one end and an attachment plug on the other end.

All internal electrical connections are made automatically when the chart drive is installed in a meter case. Spring-mounted plungers connect with a contact block on the case. Meters ordered with spring drives can have this contact block mounted on the case, for future use of an electric drive, if desired.

The shifting mechanism to change from inches per hour to inches per minute is built into the timing motor gear train. It is completely enclosed and needs no attention in service. The shift can be made manually by moving a shift lever on the right-hand side of the drive, or it can be done electrically by means of a shift coil incorporated in the drive, Figs. 10 and 13. Electric shift coil ratings available are shown in the table on page 6.

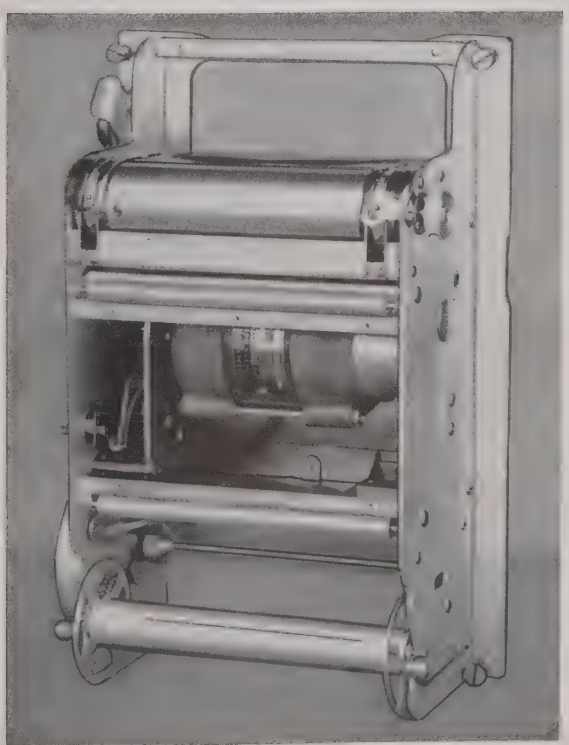


FIG. 12—*Removal of the cover plate shows the Selsyn receiver in place. Connections are made at screw terminals on the back plate.*

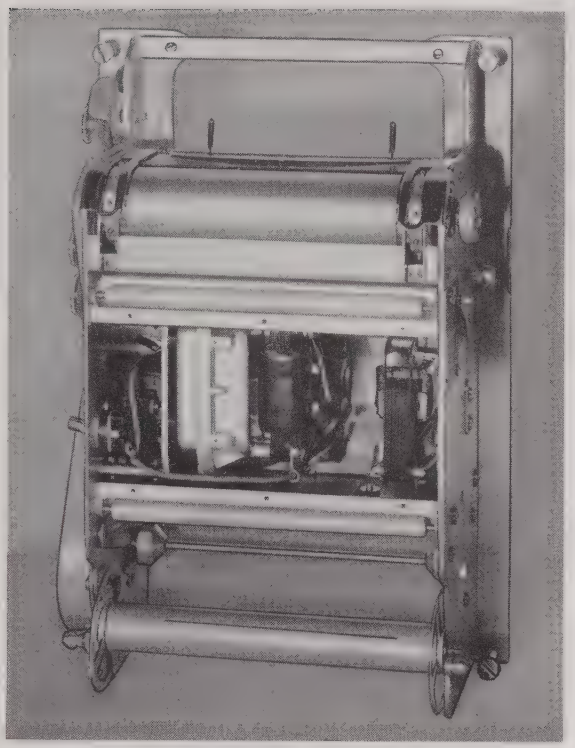


FIG. 13—*The synchronous chart drive with the instruction (cover) plate removed shows, left to right, the reroll motor, synchronous timing motor and, extreme right, the electric shift mechanism. (Used only in Type 4A). Presence of this mechanism does not prevent shifting chart speeds manually by means of the lever on the right-hand side plate*

Selsyn Chart Drive, No. 60

To meet the need for an electrical drive in which travel of the chart is proportional to some quantity other than time, E-A has developed a chart drive having a small internal Selsyn. The rotation of this internal Selsyn is controlled by a remote Selsyn transmitter. The Selsyn receiver and transmitter are for 120 volts, 60 cycles only. These drives have a coupling shaft on the left side only for coupling to a phantom chart drive in a twin recorder.

Gearing is such that with ¾, 1½ or 3 inch change gears in place, one revolution of the Selsyn will propel ¼, ½ or 1 inch of paper under the pen point. If the application is such that the driving source can reverse, the transmitting Selsyn must be installed with a clutch mechanism to prevent reversed rotation. Chart travel must always be in the forward direction. The speed of the Selsyn should not exceed 180 RPM.

The most frequent uses of this drive are: position of remote objects, level of material in a bin, X-ray or other types of thickness gauges where linear distance on the chart is proportional to travel of metal strip or passage of material through rolls.

Phantom Chart Drives

No.	Type	Chart Travel	Recommendations
6X	Spring reroll, without clutches	Phantom drives contain no power unit. One revolution of coupling shaft propels ¾, 1½, 3, 6 or 12 inches of paper under pen point with corresponding gears in place. Furnished complete with coupling. See section on Driving Chart from an External Source, page 11.	Use in left side of twin meter equipped with spring drive. Also where chart motion is proportional to some quantity other than time, no AC is available and driving source has restraining torque when chart is not in motion.
6C	Spring reroll, with drag clutch		Use where chart motion is proportional to some quantity other than time, no AC is available and driving source has no restraining force when chart is not in motion. Use with external motor.
6CC	Spring reroll, with drag and back-up clutches		Use where chart motion is proportional to some quantity other than time, no AC available, driving source has no restraining force and can reverse rotation. Coupling must be made on right side.
6EX	Electric reroll, without clutches		Use in left side of twin meter equipped with synchronous or motor-wound spring chart drive. Also where chart motion is proportional to some quantity other than time, AC is available and driving source exerts restraining torque when chart is not in motion.
6EC	Electric reroll, with drag clutch		Use where chart motion is proportional to some quantity other than time, AC is available and driving source does not exert restraining force when chart is not in motion. Use with external motor.
6ECC	Electric reroll, with drag and back-up clutches		Use where chart motion is proportional to some quantity other than time, AC is available, driving source exerts no restraining force and can reverse rotation. Coupling must be made on right side.

Electric reroll motors are the same as those used in 4 and 4A chart drives, page 6.

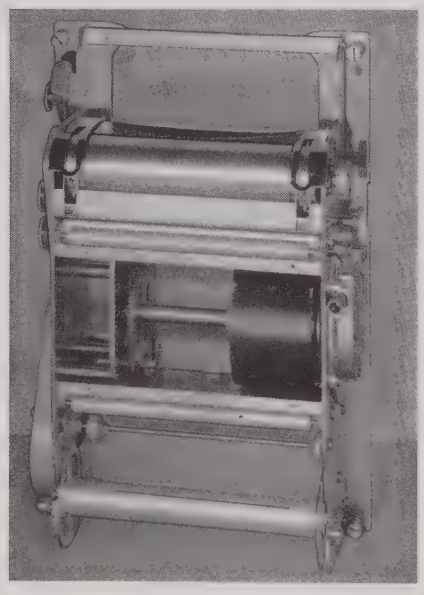


FIG. 14—*Phantom chart drives with spring reroll are used in twin recorders having hand-wound spring power drives*

PHANTOM CHART DRIVES were developed primarily for use in twin recorders, the chart being advanced by the power drive in the other half of the twin. The phantom consists of a chart carrying and reroll mechanism but it has no driving means. It must be coupled to a power chart drive or to some other external driving source. It is admirably suited to those applications where the chart is being driven proportional to some quantity other than time, such as distance traveled by an automobile, depth of a probe in an oil well or movement of the ram in a hydraulic press.

Phantom chart drives are furnished with either spring or electric reroll mechanism. When coupled to a power chart drive in a twin recorder, either type 6X or 6EX is used. When the phantom is used with an external driving means, consideration must be given to the characteristics of the source. If it always exerts a restraining force, even while not in motion, types 6X or 6EX can be employed. If the external driving source does not exert any restraining torque when the chart is not moving, type 6C or 6EC should be used. A drag clutch in these two drives prevents the reroll from pulling the chart through the drive. Where the external driving source can reverse rotation, types 6CC or 6ECC should be used. These two types include a back-up clutch to prevent reverse travel of the chart. Torque required at the coupling shaft to slip the drag clutch varies between ½ and 1¼ inch-pounds, depending on the type of phantom and the ratio of change gears used.

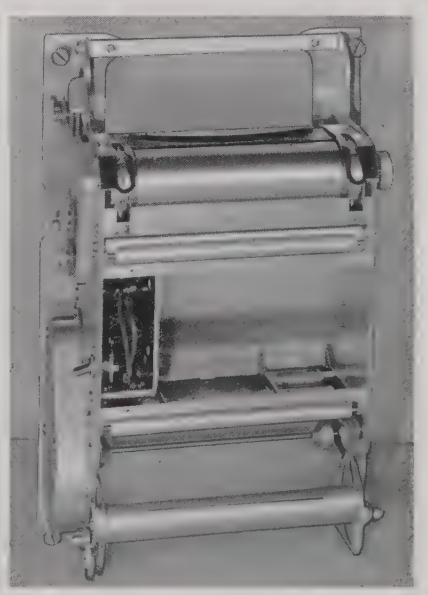


FIG. 15—*Phantom drives with electric reroll are used in twin recorders having motor-wound spring or synchronous power chart drives*

External Motor Attachments

TYPE		Chart Speeds Inches per Second	To Run chart at High Speed	Time Required for Chart to Reach High Speed[b]	Recommendations
N	Second Feed non-reset	¾, 1½, 3[a]	Apply Voltage	AC: 1/12 Sec. DC: 1 6 Sec.	Use where time of day of the rapid variation of the measured quantity is not important and length of high-speed runs may be variable.
R	Second Feed, with Time Reset	¾, 1½, 3[a]	Close Trip Circuit		Use where time of day of the rapid variation of the measured quantity is important. These drives reset the chart to correct time of day at the end of each high-speed run.

[a] When combined with 51, 52 or 52A chart drive, use only ¾ inch per second. [b] Chart starts moving approximately 1/25 second after motor is energized.

NOTE: External motors are designed to take over the propelling of the chart from a powered internal drive by slipping a clutch. External motors have the capacity to slip only one clutch.

INCREASING COMPLEXITY of control systems, rapid handling of short circuits and faults, as well as the recording of transient phenomena in the industrial plant and research laboratory have made the use of high chart speeds necessary. Slower variations of the measured quantity can be handled by the minute speeds in chart drives Nos. 2, 2A, 4, 4A, 52 and 52A. For more rapid variations, two styles of external motor attachments are available providing chart speeds in inches per second.

Type N (non-reset) should be used where the time of day of each high-speed operation is of no importance, as in industrial testing and research. The type N drive may be started and stopped by the toggle switch provided on the drive. Where the high-speed operation must be initiated from a remote point, this switch is moved to the "on" position and another switch or pair of relay contacts used in the supply circuit to start and stop the motor.

Type R (reset) starts the motor when its trip circuit is closed and the motor continues to run for 24 seconds. The trip circuit must remain closed for 1/5 second or more to insure lock-in, which may require an auxiliary time delay relay. An operation recorder or chronograph pen connected across the relay coil will show the time and duration of the pulse initiating the high-speed action. If the trip circuit is open at the end of 24 seconds, the chart reverts to slow speed at the correct time of day.

A push-button switch is provided on the type R drive so that the high-speed operation can be initiated at the recorder for testing purposes. There are four terminals on the type R attachment. Two terminals are marked "Volts" and should be connected to an unfailing source of power of the same rating as the motor. The other two terminals are marked "Trip" and the push-button switch merely short-circuits these two terminals. A pair of relay contacts, connected across these terminals, can be used to perform this function in fault recording. Voltage must not be applied to these terminals.

Recorders with type R attachments are useful instruments on power systems to provide details of a

FIG. 17—*AC Type N external motor attachment mounted on a portable recorder. The switch visible on the top of the gear box starts and stops the motor or control can be accomplished from a remote point*

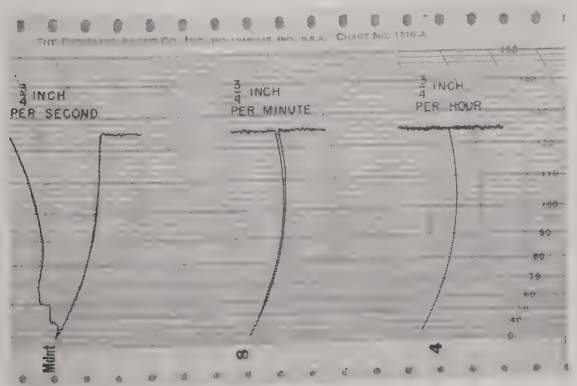


FIG. 16—*Records of the same disturbance at three different chart speeds show how the high speed record reveals more detail*

Electrical Data

Motor Rating	Volt-Amperes	Watts	Starting Amperes	Running Amperes
12 Volts DC	..	22	8.0	1.80
24 Volts DC	..	22	4.0	0.90
48 Volts DC	..	22	2.0	0.45
125 Volts DC	..	22	0.7	0.18
250 Volts DC	..	22	0.35	0.09
120 Volts, 50 cycles*	60	23	5.0	0.50
120 Volts, 60 cycles*	62	23	5.0	0.52

*AC external motors are of the Synchronous type.

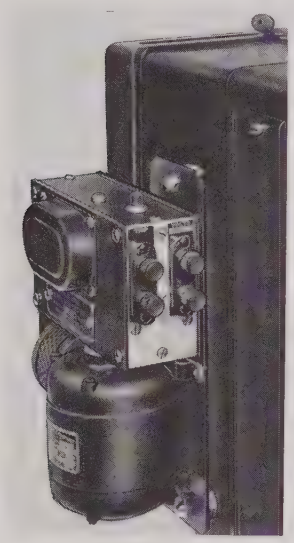


FIG. 18—*Rear view of DC, Type R external drive showing terminal arrangement. The "Trip" terminals are shorted by the momentary-contact switch shown on top of the gear box*

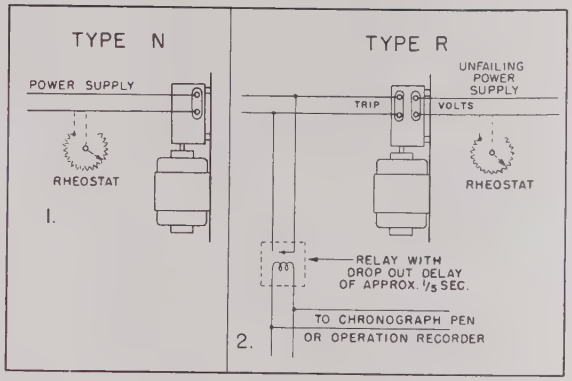


FIG. 19—*Schematic connection diagrams (1) Type N and (2) Type R external drives. The rheostat shown dotted is used for speed adjustment with DC motors. A remote switch or pair of relay contacts can be connected across the "Trip" terminals of Type R drives to accomplish automatic operation. Type R drives can be operated in parallel if desired*

disturbance. They serve as adjuncts to automatic oscillographs and have the advantages that they can record a much longer transient or several transients on one chart, without servicing the recorder between records, and the high speed records are immediately available. There is no delay while films are developed.

Normally, the chart runs at ¾ inch per hour. When a disturbance occurs, the chart increases its speed 3600 times to ¾ inch per second. Like a slow motion camera this high chart speed gives a detailed record of the disturbance and its effects. When conditions return to normal, the drive resets the chart to correct time of day and resumes operation at slow speed, ¾ inch per hour. Type R records can show time, duration and sequence of operations at various parts of the system. Study of the records enables the engineer to determine the most suitable relay settings to limit the effects of similar faults in the future. Protective apparatus can be checked and system stability improved.

Chart Speeds

The second feed drives provide ¾, 1½ and 3 inches per second of chart travel. Perhaps the most widely used is ¾ inch. It gives a record which is sufficiently open to show all the changes that most of the measuring elements can follow. When combined with 51, 52 or 52A internal drives, external motor drives must not be used above ¾ inch per second. If power to these three types of internal drives, as well as 4 and 4A drives, should fail, they will reroll only 18 inches of chart.

Coupling Chart Drives

It is often advantageous as well as economical to couple the chart drives in adjacent instruments. This is particularly true when two or more instruments, equipped with spring chart drives, are measuring different quantities related to a common problem. In such a case, the charts must be synchronized as to time or the records cannot be evaluated. Synchronous chart drives, Nos. 4 and 4A need not be coupled. If energized from the same source of power and started with a single switch they will remain in synchronism. All chart drives, except the Selsyn, have a through shaft for coupling. Selsyn drives can be coupled to a phantom only on the left side.

FIG. 20—*It is often desirable to couple the chart drives of two spring drive meters to synchronize their charts, as in recording KW and KVA, Volts and Amperes, Pressure and Position, etc.*

Couplings

Two styles of couplings are available for driving two or more charts in time synchronism. One style is designed to transmit considerable torque. It is used between an external motor and the chart drive in a recorder, since the torque transmitted is high to drive the paper at high speed and to slip the take-over clutch. The other style fits tight on each coupling shaft and eliminates practically all possibility of backlash between chart drives. It is designed for transmitting light torque such as that between a

Coupling Styles and Application Data

High Torque	Low Torque	Spacing of Cases Center to Center (Inches)	Distance Between Flush Flanges (Inches)	Overall Coupling Length (Inches)	USE
10090A	.....	8 7/16	.....	1 21/64	Between External Motor and Internal Drive
.....	12674B	8 7/16	.....	1 3/16	Twin Flush Cases, AWT-V, AWT-R, AWT-D
10090B	.....	8 3/4	.....	1 5/8	Twin Wall and Twin Switchboard Cases Twin Flush AWT-N Two Single Wall or Switchboard Cases
.....	12674A	8 3/4	.....	1 1/2	Twin Wall and Twin Switchboard
10090C	.....	10 3/4	.....	3 5/8	Twin Flush AWT (Two door style) Portable to Portable
.....	12674C	12 1/2	1 3/4	5 1/2	Two Single Flush Cases AW-R or AW-V
.....	12674D	10 3/4	.....	3 5/8	Twin Flush AWT (Two door style) Portable to Portable Two Single Flush Cases AW-R or AW-V
.....	12674E	12 5/16	1 3/4	5 1/4	Two Single Flush, AW-D Two Twin Flush, AW-D
10090G	12674F	10 9/16	0	3 7/16	Two Single Flush, AW-D Two Twin Flush, AW-D

power chart drive and the phantom chart drive in a twin instrument.

Various lengths of couplings are available to meet all mounting conditions and spacing between meter cases as shown in the accompanying table. Also available are collapsible couplings in both high and low torque styles to handle spacings above 1 3/4 inches.

Driving Chart from an External Source

The through shaft can also be used for driving the chart from an external source proportional to time or any other quantity. Between the shaft and the escapement or synchronous motor inside the drive, a clutch is provided to prevent damage to the timing device when an external source of power takes over the driving of the chart. The external power source must be sufficiently large to overcome friction in this clutch (one to two inch-pounds).

The external source can be attached to either side of the chart drive. Each revolution of the through-shaft propels 3/4, 1 1/2, 3, 6 or 12 inches of paper under the pen point with the corresponding gears in place. Paper speeds in excess of 3 inches per second should not be used and, usually, 3/4 inch per second gives all the information required. If there is any possibility

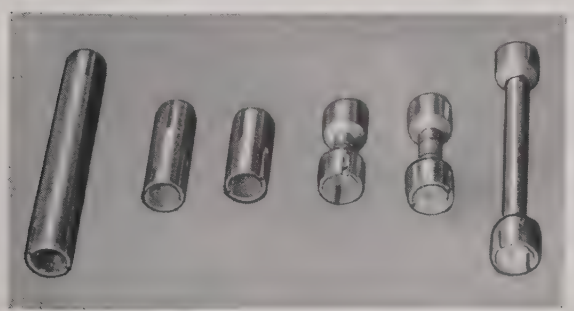


FIG. 21—*Illustrated, left to right, are couplings 12674 C, A, B and 10090 A, B, and C whose applications are listed in the table above*

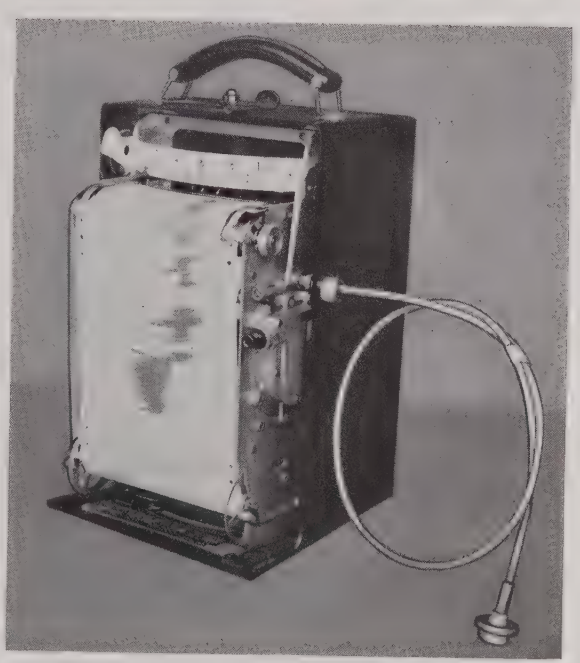


FIG. 22—*A flexible cable can be used to drive the chart by coupling to the through shaft. If the external power source can reverse rotation, the chart drive must be equipped with a back-up clutch*

that the external source can reverse, the chart drive must be equipped with a back-up clutch to prevent running the chart backward. This clutch is mounted on the right-hand side of the drive and the external driving source must then be attached on the right to protect the internal chart drive. It is a simple matter to add a back-up clutch to an existing meter.

Driving Chart from Speedometer Cable

In some work, it is desirable to drive the chart from the speedometer cable of a car or truck, proportional to distance traveled. This is quite often done in radio and TV field-strength surveys and in uranium pros-

pecting. It will usually be found that the speedometer shaft makes 1000 revolutions per mile and it is necessary to use step-down gearing. The following table shows the chart travel per mile with different change gears in place—

External Gear Ratio	Chart Travel—Inches per Mile with Various Change Gears in Place				
	¾	1½	3	6	12
100:1	7.5	15	30	60	180
150:1	5	10	20	40	80
200:1	3.75	7.5	15	30	60
300:1	2.5	5	10	20	40
400:1	1.87	3.75	7.5	15	30
600:1	1.25	2.5	5	10	20

Speed reducers to provide these reductions are available from a number of manufacturers. The chart drive of the meter must always be equipped with a back-up clutch and driven from the right-hand side, since a vehicle will reverse its travel.

Charts having major arc spacings of 1- and 1½-inches are available and the chart should be selected to make it as easy as possible to read. For example, with 100:1 reduction gearing and ¾-inch change gears, the distance between major 1½-inch arcs represents 0.2 mile. Similarly, with 150:1 reduction gears and 1½-inch change gears, the distance between 1-inch arcs represents 0.1 mile.

Clarke Mobile Chart Drive Unit

Complete equipment for driving charts of Model AW recorders from the speedometer cable of a car or truck is available from NEMS-Clarke, Inc., 919 Jesup-Blair Drive, Silver Spring, Maryland. The device consists of a drive unit to be mounted on the left-hand side of the recorder, a speedometer cable tee and the necessary flexible shafts. The speedometer of the vehicle remains in service while this device is being used.

A spring-positioned gear is included in the auxiliary drive so no damage to the meter occurs when the vehicle moves in reverse and the chart drive does not need to be equipped with a back-up clutch. Chart travel of 1, 2, 4, 8 or 16 inches per mile travel is provided with ¾, 1½, 3, 6 or 12 inch change gears, respectively, in place. In ordering from NEMS-Clarke, specify the make, year and model of the vehicle and give the style number of the chart drive in the recorder. (As 78R, 80M, etc.) This number appears on the chart drive nameplate on the left-hand side plate.

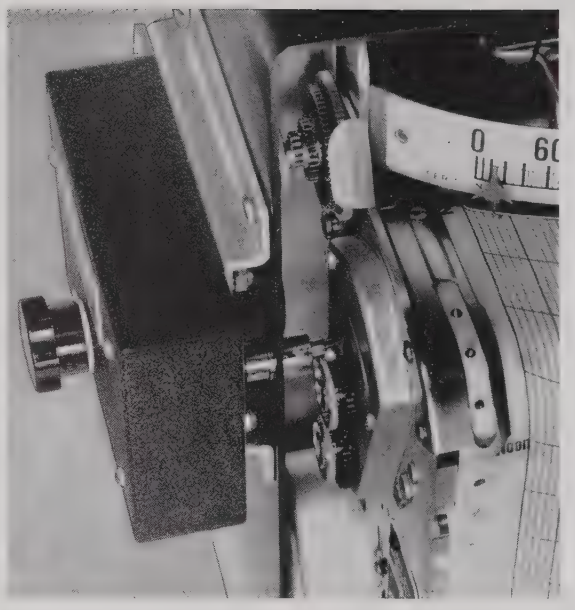


FIG. 23—*The Clarke recorder unit couples to the through shaft of the chart drive. It contains a spring-positioned gear to prevent damage to the chart drive when the vehicle travels in reverse*

How to Order

1—From the tables at the top of pages 4, 6, 8 and 9, select the internal drive or combination of internal drive and external motor that fits the requirements of the recording job to be done.

2—With 2A, 4, 4A, 6EX, 6EC, 6ECC, 51, 52, 52A or any external motor, specify the voltage and frequency. See page 2.

3—If chart drive is being purchased separately for an existing recorder, give serial number.

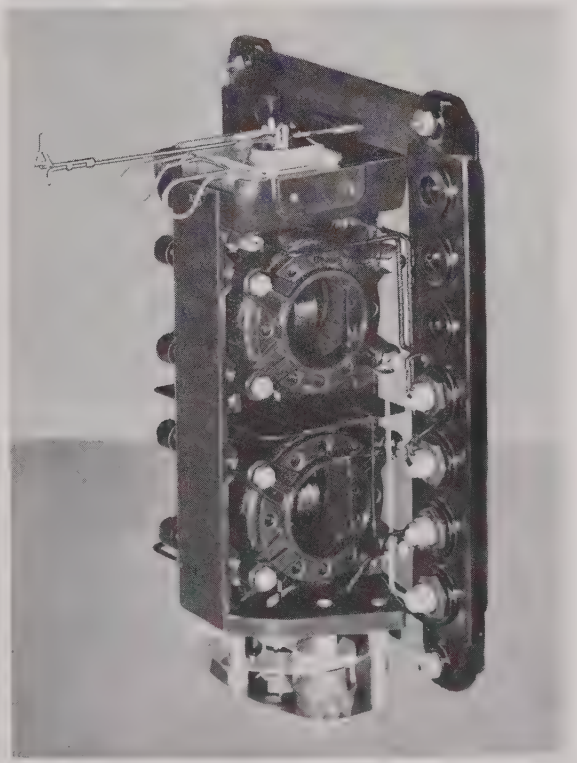
a—Where new drive is to be interchangeable with a drive bearing style No. 79 or below, a new scaleplate will be required. Specify scale range and legend.

THE ESTERLINE-ANGUS COMPANY
Pioneers in the Manufacture of Graphic Instruments
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

ESTERLINE-ANGUS
Recording

Alternating Current Ammeters
Alternating Current Voltmeters
AC-DC (Utility) Voltmeters

ELECTRODYNAMOMETER TYPE



For over fifty years our design engineers have concentrated their efforts on building the best recording instruments. Since no recorder can produce records any more accurate than its measuring element can measure, a considerable portion of those efforts has gone into perfecting the measuring element. In the following pages, we are concerned with the electrodynamometer measuring elements used in AC ammeters, AC voltmeters and AC-DC (Utility) voltmeters. Similar electrodynamometer measuring elements are used in wattmeters, varmeters, KVA, power factor and frequency recorders.

AC Ammeters, AC and AC-DC (Utility) Voltmeters using Electrodynamometer Measuring Elements

An electrodynamometer measuring element consists of two pairs of stationary coils, called field coils, and two moving coils on a single staff, called armature coils. These parts are held in the proper relation to each other by a molded bakelite frame, Fig. 1. The top of the bakelite molding forms a cavity for holding the inkwell, Fig. 2, and has two drain tubes that carry away any spilled ink. The upper bearing support is sealed so that ink cannot flow down around it.

The armature coils are carried on a staff, Fig. 1, which has a pen fork on its upper end to hold the pen element. Immediately below the pen fork is a canopy that covers the upper bearing and prevents any extraneous material from getting into the bearing or traveling down the staff. Near the lower end of the staff is an aluminum vane that rotates in the field of two adjustable damping magnets, to control response speed. The lower tip of the moving member is a hardened steel, hemispherical pivot, which rests in a sapphire jewel. This jewel is spring mounted, protecting it against injury from mechanical shock.

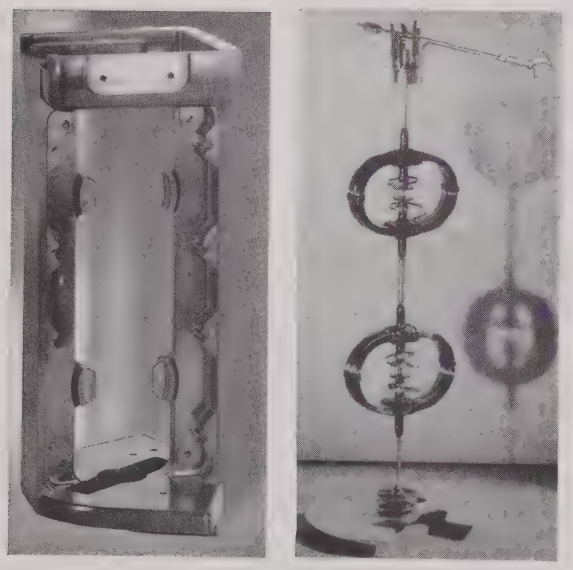


Fig. 1—*The molded bakelite frame (left) forms a rigid support for the fixed and moving coils of the measuring element and provides a high degree of insulation between current carrying parts. The moving element or armature of the dynamometer (right) consists of two coils, mounted on a solid staff which carries the pen fork, restraining springs, damper vane and steel pivot. The pen element, shown in place, is easily taken out or replaced without tools*

Each measuring element has its damping magnets set properly at the factory for the weight and torque of its moving system. When it is necessary, to meet specific operating conditions, the magnet settings can be changed in the field. The effect of different magnet settings and the flexibility of the response that can be obtained, are shown in Figs. 7 and 8.

AC ammeters and voltmeters of the dynamometer type record RMS values independent of wave form. The magnetic circuits are air-cored. The absence of iron makes these measuring elements completely insensitive to ordinary variations in power system frequency. Some of them are accurate over the entire range of 25-400 cycles. For higher frequencies, lower burden, uniform scale or a combination ammeter-voltmeter, the rectifier type instruments in Catalog Section 48 are recommended.

The problem of maintaining a fixed relation between stationary and moving coils is solved by the molded bakelite frame. The fixed relation is so accurately maintained that a measuring element can be disassembled and put back together without changing its calibration. This frame also helps to solve another problem, that of providing adequate insulation between the various parts. How well that is accomplished is attested by the fact that the measuring elements withstand a 5000 volt AC insulation test for one minute between all current carrying parts and ground.

The measuring element, with its terminal boards, is a complete unit which can be installed in or removed from the recorder case without disturbing its electrical connections. This measuring unit is also interchangeable with other elements, such as the permanent-magnet, moving-coil type. While E-A dynamometer measuring elements are essentially two-element devices, they are used as single element meters, in AC ammeters, and AC and AC-DC voltmeters. The two halves of the measuring element are connected astatically to eliminate external field effects.

AC Ammeters

In an AC ammeter, both the stationary and moving coils are fed through one pair of leads, connected into the measured circuit or to the secondary of a current transformer.

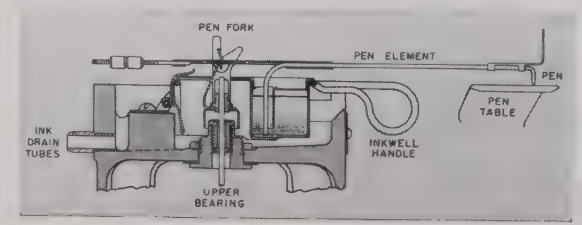


Fig. 2—*Cross-sectioned view shows the top of the measuring element frame, with inkwell and pen element in place, drain tubes that prevent spilled ink from reaching any current-carrying parts, as well as the canopy protecting the upper bearing*

There are two styles of AC ammeter measuring elements. Style No. 316 is used for 0-5, 0-5/10, 0-7.5, 0-10, 0-15, and 0-20 ampere instruments. It has a small, internal current transformer which supplies the current to the moving coils. This transformer protects the instrument during heavy overloads of short duration and makes possible an instrument having a low burden, as shown in the table on page 6.

Measuring element Style No. 317 is similar to No. 316 but is modified to produce odd full scale ranges that cannot be obtained with the No. 316 element. No. 316 can be used on 25-400 cycles and No. 317 on 25-240 cycles, all with 1% accuracy. The No. 316 and 317 elements cannot be used on DC because of the internal transformer.

Leads

Lead lengths are not critical and long leads may be used almost at will, without affecting calibration of the meter. Where it is known that the current transformer is loaded nearly to capacity, long leads should not be used without calculating the additional burden they will impose.

Scales and Charts

When an AC ammeter is to be permanently connected to one current transformer, the scale and chart range should correspond to the primary rating of the transformer. Direct reading charts can be furnished for nearly all applications. (See 1300 series charts in catalog section 90.) Portable instruments are usually supplied with a 0-5 ampere scale and chart, and a multiplying factor (equal to the current transformer ratio) is used to interpret the chart.

Scales and charts are approximately quadratic, being spread out near full scale and condensed near zero. Because of this feature, it is impossible to read values below one-third of full scale accurately but the useful part of the scale can be read within one percent of full scale value.

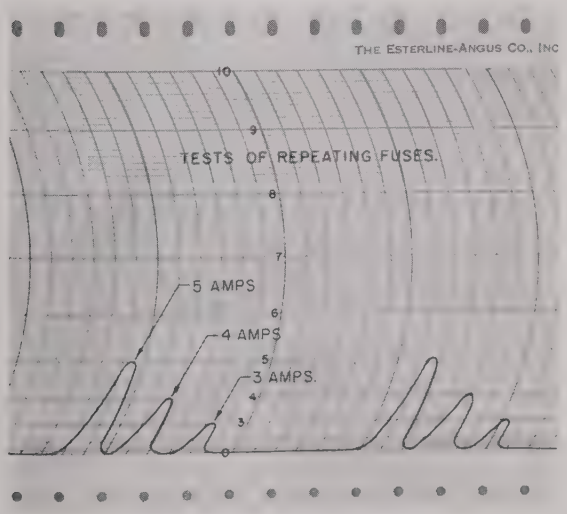


FIG. 3—*Graphic ammeter chart of the operation of a 25,000 volt repeating fuse, shows tests of 3, 4 and 5-ampere elements*

FIG. 4—*Portable recorder with hand-wound spring chart drive, pen element in tie-up card, ready to be packed for shipment*

Ammeter vs. Wattmeter

It is often necessary to choose between an AC ammeter and AC wattmeter to record some particular condition. Where current is the governing factor, as in balancing phases of a transformer bank or distribution system, studying cable heating, etc., the AC ammeter is the correct choice because it records the value of the key factor in the situation being investigated.

Where work being done or the power load on equipment, particularly AC motors, is the paramount condition to be studied, the AC wattmeter is the correct choice. The wattmeter takes into account changes in line voltage and power factor and its record shows true power input accurately. AC ammeters cannot do this and it is possible to misinterpret ammeter records unless these facts are borne in mind. An example will serve to show the difference between ammeter and wattmeter records. The KW input to a squirrel cage induction motor at no load will usually be less than 10% of the full load power, while the current will be anywhere from 25 to as much as 50% of full load current. Power varies over a wider range than current and gives a better picture of load characteristics.

Motor starting currents are handled better by a wattmeter, since the starting surge is very low power factor. When an ammeter is used, the starting current can be kept off the record by short circuiting the recorder during starting or using a time delay relay, although this precaution is considered necessary only on certain unusual applications.

Switching Ammeters

When an ammeter is to be switched from one circuit to another, the switch must short-circuit one current transformer before it disconnects the ammeter and connects it to another current transformer.

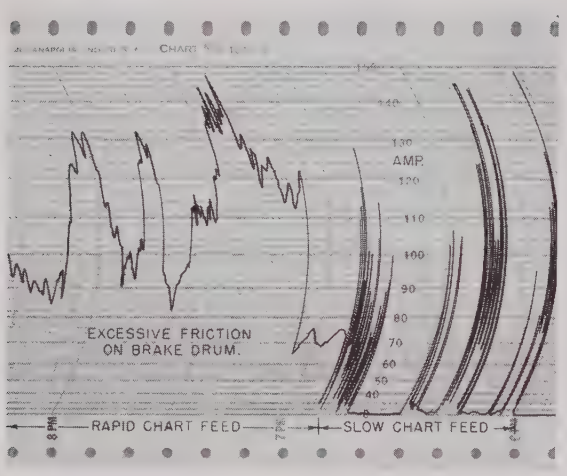


FIG. 5—*Five similar mine hoists were tested and four performed satisfactorily. One produced this record, shown with both slow and rapid chart speed. Investigation located a high spot on the brake drum, rubbing on the band during each revolution*

Applications

Some suggested uses, both for portable and permanently installed AC ammeters are in recording:

- Unbalance in secondary networks
- Grounded neutral fault currents
- Phase balance in office building distribution systems
- Currents in cables, feeders, buses to find overloaded elements of a system
- Transformer loads to study heating
- Welding, continuous or spot
- Operating cycles, where the record is not being interpreted in terms of work done
- Repetitious operations, such as grinding and polishing, machine tool time studies
- Water velocity in large ducts or conduits (salt injection method)
- Dynamic braking
- Fuse and circuit breaker operating values

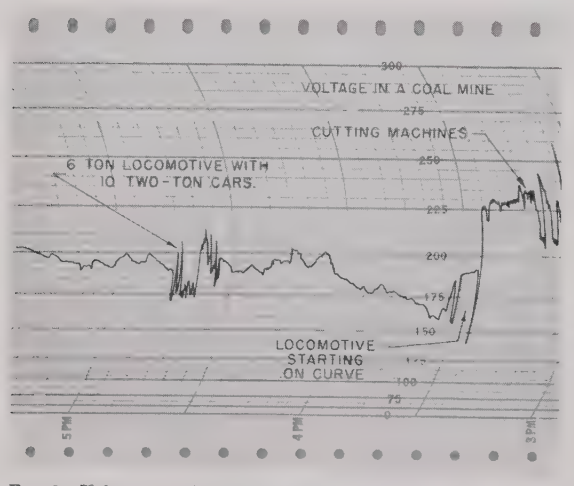


FIG. 6—*Voltage record from a feeder in a coal mine. Locomotives could not pull the loads because the voltage dropped from 275 to 140 when the locomotive started*

AC and AC-DC (Utility) Voltmeters

Voltmeters using dynamometer measuring elements are of two types, those intended for AC use on a specific frequency and those intended for use on DC and multiple frequency AC. Internal coil connections are shown on page 7. A tapped resistor effects the proper calibration for the voltage ranges provided. This resistor is housed in a multiplier box on the back of portable and flush meters and separately mounted for meters in wall or front switchboard cases.

Three styles of measuring elements are available to cover the ranges shown on page 7. Style No. 340 is used in AC voltmeters calibrated for a specific frequency, usually 25, 50 or 60 cycles. It can be adjusted

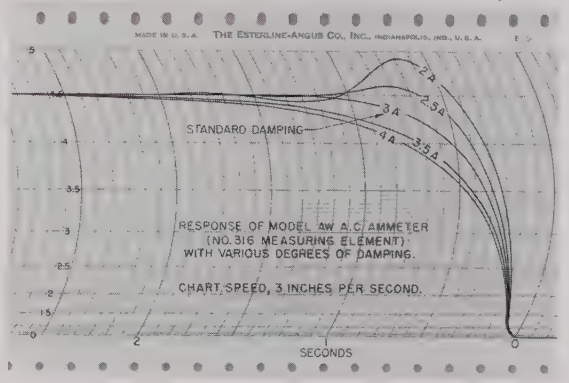


FIG. 7—*Standard damping of ammeters is somewhat heavier than critical and gives a speed of response of about 1.15 seconds*

for any full scale value between 143 and 800 volts. The same measuring element, with a frequency compensating network, is used in AC-DC (Utility) voltmeters. Voltage ranges from 150 to 800 volts are available. These utility voltmeters are calibrated for DC and for AC frequencies of 25-60 cycles. This measuring element draws 0.13 ampere at full scale.

Style No. 341 is available to provide ranges between 0-50 and 0-250 volts. The current drawn by this lower voltage element is 0.38 ampere.

Style No. 342 element can be calibrated for any range between 0-100 and 0-600 volts, 25, 50 or 60 cycles. Full scale current is 0.18 ampere.

For ranges below those for which a standard measuring element can be calibrated, it is necessary to use a meter with a 0-150 volt range (No. 340 measuring element) and a step-up potential transformer. A potential transformer with primary ranges of 25, 50 and 75 volts to 150 volts secondary is available. For ranges down to 0-5 volts, 60 cycles, use the rectifier type AC voltmeter with 0-150 volt range and a 5/15/30: 150 volt step-up potential transformer. See Catalog Section 48.

Leads

Lead resistance is not a critical part of the measuring circuit and long leads are frequently used. Binding post terminals may be used on portable instruments instead of standard 5-foot, plug type leads.

Scales and Charts

Permanently mounted instruments are provided with a scale and chart to place the line voltage at a convenient point on the chart. For example, a scale of 0-150 volts is used on 120 volt circuits, 0-300 volts on 240 volt circuits and 0-600 volts on 480 volt circuits. When potential transformers are used, the recorder scale and chart range can be selected for either primary or secondary values.

Portable multi-range meters should have a scale and chart range corresponding to the lowest self-contained range or the range that will be most widely used. For example, a 0-150/300/600 volt recorder, used for general purpose testing, should have a 0-150 volt scale and chart.

Scales and charts are approximately quadratic, (1300 series in catalog section 90). The normal record

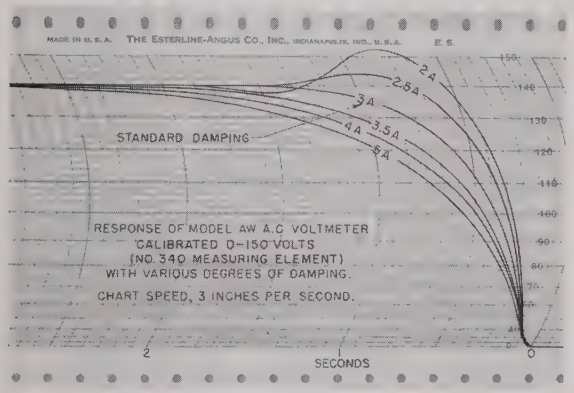


FIG. 8—*With standard damping, the response speed of voltmeters is about 1.3 seconds*

should be kept between ½ and ¾ scale in the open portion of the scale, and the lowest useful value to be recorded must be above ⅓ full scale.

Applications

The uses of voltmeters, while simple to state, are very important. Probably more plant operating troubles result from improper voltage than any other single cause. Voltage surveys with portable meters, plus permanently mounted recorders at strategic points will show when operating conditions must be improved, to avoid future trouble.

Some suggested applications are studies of:

- Line, bus and feeder voltage records on power systems and plant distribution systems
- Faults (with quick-trip chart drive)
- Customer complaints
- Operating troubles: motors fail to start, blown fuses, overheating
- Welding (lower voltage meters)
- Safety equipment tests (rubber gloves, sleeves, etc.)
- Operation of voltage regulators
- Power rectifier input and output voltages

Rectifier Ammeters and Voltmeters

Rectifier type AC instruments, described in Catalog Section 48, are suggested where:

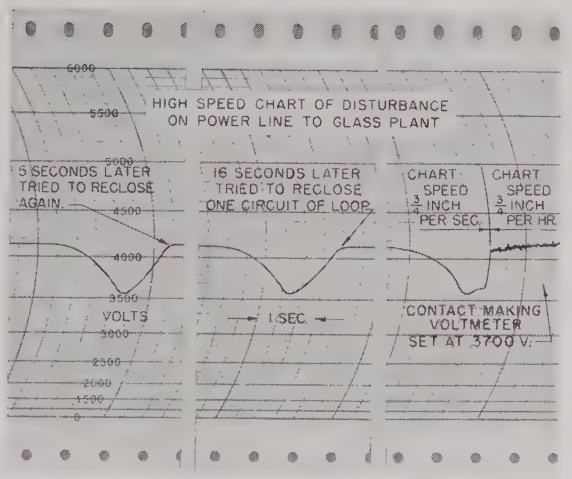


FIG. 9—*This record was taken in a glass plant with a voltmeter having a Type R external motor drive. Continuity of service at the proper voltage is extremely important in such plants. Failure may cause loss of product and extensive damage to equipment*

1—a low burden is necessary, as when using a low-range, split-core current transformer.

2—measuring the AC voltage of a low power source.

3—a multi-purpose instrument is advantageous, such as a combination AC-DC ammeter-voltmeter.

4—voltage ranges down to 0-5 volts are required. Use 0-150 volt range on the rectifier recorder and a 5/15/30:150 volt, 60 cycle, step-up potential transformer.

These instruments have the advantage of being usable over a wide range of frequency (50-800 cycles) and they have uniformly divided scales and charts. Rectifier recorders read average values and are scaled in RMS values based on sine wave. Changing wave form changes the ratio of average to RMS values, but such variations on commercial systems are usually slight.

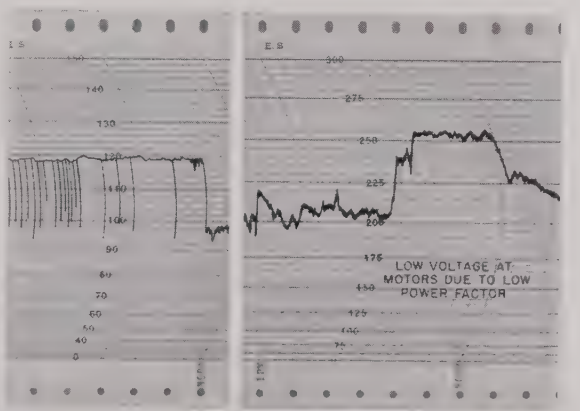


FIG. 10—*The effect of grounds on a lighting line where it passed through trees is shown at the left. Voltage, in the right-hand chart, was normal during the noon period, but dropped as low as 200 when the plant resumed work. Troubles due to low voltage evidence themselves in blown fuses, overheated motors, and decrease in production*

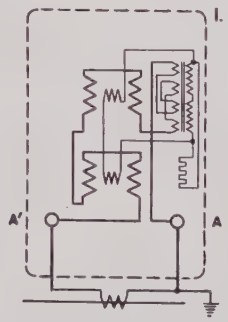
Model AW AC Ammeters

Two-element Astatic Electrodynamometer Type
Measuring Elements Nos. 316 and 317

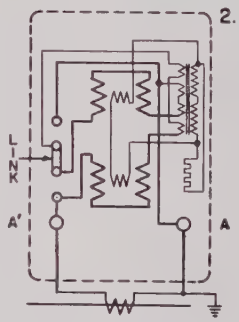
Standard Ampere Range	Measuring Element Style No.	Burden in VA		Impedance in Ohms		Power Factor		Voltage Drop		Frequency Limits for 1% Accuracy	Calibration Limits*	
		25 cy.	60 cy.	25 cy.	60 cy.	25 cy.	60 cy.	25 cy.	60 cy.		Min.	Max.
0-5†	316	6.6	9.5	0.26	0.38	0.98	0.68	1.3	1.9	25-400	0- 4.8	0- 5.5
0-7.5	316	10.5	15.0	0.19	0.27	0.90	0.63	1.4	2.0	25-240	0- 6.9	0- 7.6
0-10	316	6.6	9.5	0.07	0.10	0.98	0.68	0.70	1.0	25-400	0- 9.6	0-11
0-15	316	10.5	15.0	0.047	0.067	0.90	0.63	0.70	1.0	25-240	0-13.8	0-15.2
0-20	316	6.6	9.5	0.007	0.024	0.98	0.68	0.33	0.48	25-400	0-19.2	0-22
0-5/10												
5 range	316	6.6	9.5	0.26	0.38	0.98	0.68	1.3	1.9	25-400		
10 range	316	6.6	9.5	0.07	0.10	0.98	0.68	0.70	1.0	25-400		

†The burden of the 0-5 ampere meter (with 316 measuring element) is 22 VA at 180 cycles; 45 VA at 400 cycles.

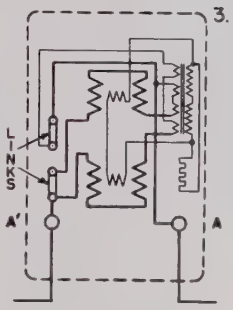
*See also Special Ranges below.



Internal and external wiring diagram, 0-5 ampere AC ammeter with current transformer



Dual-range 0-5/10 ampere AC ammeter connected on 5-ampere range with current transformer



Dual-range 0-5/10 ampere AC ammeter connected for 10 amperes

Charts—Approximately quadratic, 1300 series, refer to catalog section 90.

Scales—To match any 1300 series chart. Lowest readable current is about ⅓ full scale. On dual-range meters, scale should match lower range. On permanently mounted meters, the scale should be selected so that the normal record will be about ¾ full scale and the maximum value less than full scale.

Zero—Left-hand only. Meter has no polarity.

Multiranges—Only the dual-range meters listed in table.

Leads—Furnished only with portable type. Standard portable leads are 5-feet long. Dual-range meters have only two leads, see diagrams 2 and 3, above.

Binding Posts—Can be furnished instead of leads on portables.

Multipliers—None required.

Damping—Adjustable magnets and damper vane.

Response Speed—With standard damping, time required for pen to complete swing one way—1.15 second.

Dielectric Test—5000 volts, 60 cycles, for one minute.

Guaranteed Accuracy—1% of full scale current.

Overload Capacity—5 ampere meter will carry 9 amperes continuously; 200 amperes for 1 second.

Special Ranges—Any single range meter within the calibration limits in table above. Also odd full scale calibrations of 3.7-4.7, 5.6-6.1, 6.2-6.8 and 7.7-8.5 A are available, using measuring element No. 317.

DC Operation—Measuring elements Nos. 316 and 317 have an internal current transformer and cannot be used on DC.

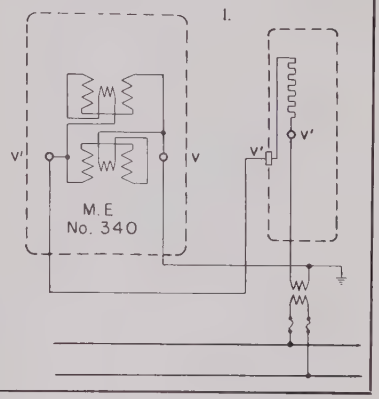
Current transformers—Must be used for currents exceeding the self-contained range, and on circuits above 800 volts.

Model AW AC Voltmeters

Two-element Astatic Electrodynamometer Type
For use on a single frequency within limits shown in Table I
Measuring Elements Nos. 340, 341 and 342

Range in Volts

0-50 0-150
0-75 0-300
0-100 0-600
0-125▲ 0-750
0-150/300
0-150/600
0-300/600
0-150/300/600
0-150/300/750
0-150/300/600/750

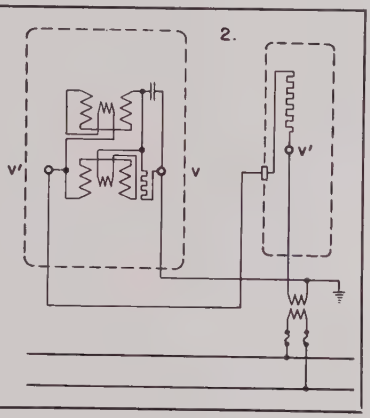


Model AW AC-DC (Utility) Voltmeters

Two-element Astatic Electrodynamometer Type
For interchangeable use on DC to 60 cycles AC
Measuring Element No. 340-B, with frequency compensating network

Range in Volts

0-150
0-300
0-600
0-750
0-150/300
0-150/600
0-300/600
0-150/300/750
0-150/300/600/750



▲No chart is available for the 0-125 volt range.

TABLE I—*Average Electrical Data—AC Voltmeters*

Measuring Element Number	Range in Volts	Approximate Full Scale Current Amperes	Approximate Reading of Standard 60 cycle Meter Used on Various Frequencies		
			DC	25 cy.	60 cy.
340†	0-150*	0.13	1.03	1.02	1.00
340	0-300	0.13	1.01	1.01	1.00
340	0-600	0.13	1.00	1.00	1.00
340	0-750	0.13	1.00	1.00	1.00
341	0- 50	0.38	1.05	1.04	1.00
341	0- 75	0.38	1.02	1.02	1.00
341	0-150	0.38	1.01	1.01	1.00
341	0-200	0.38	1.00	1.00	1.00
341	0-250	0.38	1.00	1.00	1.00
342	0-100	0.18	1.01	1.01	1.00
342	0-125▲	0.18	1.01	1.01	1.00
342	0-150	0.18	1.00	1.00	1.00
342	0-300	0.18	1.00	1.00	1.00
342	0-600	0.18	1.00	1.00	1.00

*This is the measuring element commonly used in AC Voltmeters for 25, 50 or 60 cycle service. Minimum calibration limit 0-143 volts.
▲No chart is available for the 0-125 volt range.
†Burden of 150 volt instrument at 120 volts, 60 cycles is 12.5 volt-amperes.

TABLE II—*Average Electrical Data—AC-DC (Utility) Voltmeters*

Range in Volts	Reading of Standard Meter Used on Various Frequencies		
	DC	25 cy.	60 cy.
0-150†	1.00	1.00	1.00
0-300	1.00	1.00	1.00
0-600	1.00	1.00	1.00
0-750	1.00	1.00	1.00

†Burden of 150 volt instrument at 120 volts, 60 cycles is 12.5 volt-amperes

Charts—Approximately quadratic, 1300 series, refer to catalog section 90.
Scales—To match any 1300 series chart. Lowest readable voltage is about ⅓ full scale. On multi-range instruments, scale should match lowest range or range most often used.
Zero—Left-hand only. Meter has no polarity.
Multi-ranges—A number of combinations not listed can be supplied.
Leads—Furnished only with portable type. Standard portable leads are 5-feet long.
Binding Posts—Can be furnished instead of leads on portables.
Multipliers—Portable and flush meters have multiplier mounted on case back. Front switchboard and wall type have one separate standard size multiplier.
Damping—Adjustable magnets and damper vane.
Response Speed—With standard damping, time required for pen to complete swing one way—1.3 seconds.
Dielectric Test—5000 volts, 60 cycles, for one minute.
Guaranteed Accuracy—1% of full scale voltage.
Potential Transformers—Required above 800 volts AC.
Special Ranges—AC or AC-DC: any intermediate ranges can be furnished. For ranges below those listed, consult factory. Consideration should be given to rectifier recorders, Catalog Section 48, for which a 5/15/30:150 volt, 60 cycle, step-up transformer is available.

Cases

Portable, wall, flush and front switchboard single case styles are available and all but portable are also furnished in twin mounting. The case bodies are die-cast, aluminum alloy, finished with dull black, baked enamel. Flush cases are equipped with fluorescent lighting for 120 volts, 60-cycles. For other frequencies, incandescent lighting is furnished.

Chart Drives

A large variety of chart drives provides the user with the utmost in flexibility to meet conditions in his particular plant. Briefly they are divided into three general classes:

Hand-wound spring
Motor-wound spring
Synchronous motor

Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. The change from inches per hour to inches per minute can be made manually by means of a shift lever, or electrically, with the addition of a shift coil inside the chart drive.

Higher chart speeds are sometimes required to study short time intervals, and external motors, providing speeds of ¾, 1½ and 3 inches per second, can be supplied. For high speed fault recording, a special form of this external drive, called Type R, resets the chart to correct time of day after each high speed run.

When instruments are combined in twin cases, both charts can be driven by a single power chart drive, mounted in the right-hand half of the twin. The other half of the twin then uses a slave mechanism, called a phantom chart drive. Phantom drives can also be used where it is desired to drive the chart from an external source.

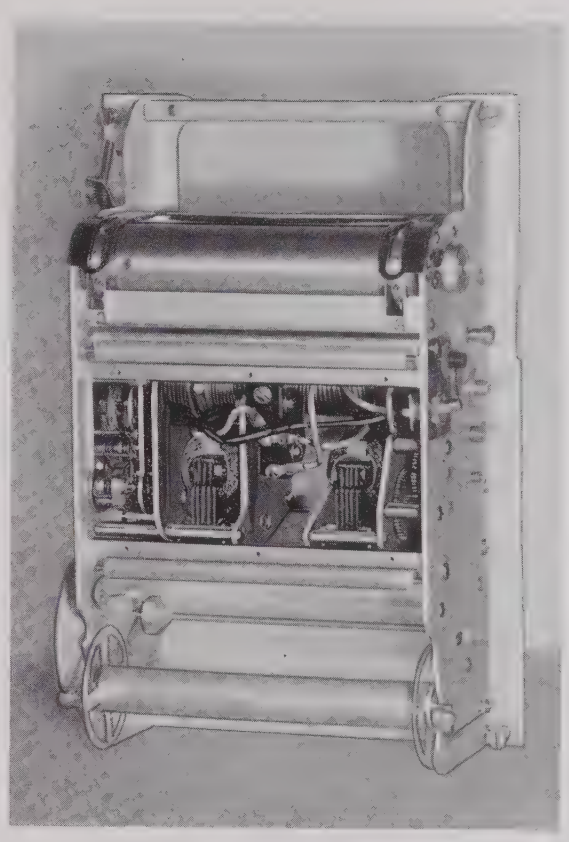


FIG. 11—*The motor-wound spring chart drive operates as a spring drive and the springs are wound periodically by motors. When the power goes off, operation will continue for at least five hours, at any standard hour feed, on the energy stored in the springs*

How to Order

Specify

1—Case Style (catalog section 15): Portable, Flush Switchboard, Front Switchboard, Wall mounting.

2—Chart Drive (catalog section 20): Hand-wound spring, Synchronous, Motor-wound spring. If electric give voltage and frequency. If electric hour-to-minute feed shift desired, give voltage and frequency.

3—Measuring Element: Full scale amperes or volts of the ranges desired. Frequency.

4—Scale and Chart: Range numbers desired on chart and scaleplate. Chart speed.

5—Current Transformer (catalog section 80): Ratio. Portable or switchboard. Are we to furnish?

6—Potential Transformer (catalog section 80): Ratio. Frequency. Portable or switchboard. Are we to furnish?

7—Accessories and Attachments (catalog section 80): Writing door, glass corner in case cover, right- and left-hand chronograph pens (give voltage and frequency), etc.

8—Supplies: (catalog section 90): Chart inspector, extra pen elements, pen points, pen point cleaner, charts, ink, carrying case, etc.

THE ESTERLINE-ANGUS COMPANY, INC.
Pioneers in the Manufacture of Graphic Instruments
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

ESTERLINE-ANGUS
Recording

AC Wattmeters

two, three and four current element

DC and AC-DC (Utility) Wattmeters

two current element

ELECTRODYNAMOMETER TYPE

The wattmeter **is perhaps the most versatile of all recording instruments. Since it records the rate of flow of energy in a circuit—the rate at which work is done—it often gives valuable information which would be difficult to determine in any other manner. Not only is it widely used to record the load on large power generators or the total load on a group of generators in a power plant, but also it is valuable in studying the performance of all types of motors driving various types of loads.**

For example, the variations in viscosity of liquids or the plasticity of pasty solids can be recorded continuously by measuring the power required to drive an agitator, stirrer, mixer or kneader. Similarly, the power input to a fan or blower may tell of an obstructed suction inlet, a slipping belt, or of leaks or unnecessary openings in a ventilating or exhaust system. Mechanical defects in a motor-driven pump will usually be disclosed by wattmeter records. The power input to machine tools may be used to study cutting tools, lubricants, and the operating cycles of the machine as a unit.

FIG. 1—*The portable recording wattmeter with its leads and some of the accessories used. These include shunts for DC use and both closed and split-core current transformers for AC use*

Electrodynamometer Type
AC, DC and AC-DC (Utility) Wattmeters

ALTHOUGH THE COILS and the internal connections are different, the construction of the measuring elements used in all electrodynamometer wattmeters is the same. The backbone of the measuring device is a heavy, rigid phenolic molding. All of the parts mounted on this frame are positioned firmly and accurately so that shocks and temperature changes do not alter the physical alignment and,

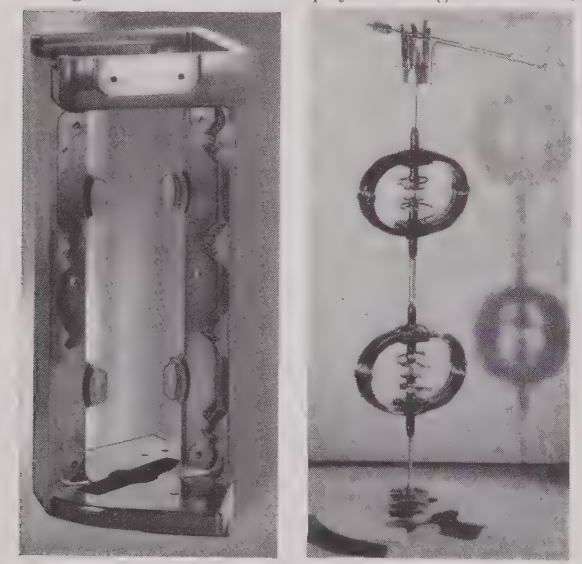


FIG. 2—*The molded phenolic frame (left) forms a rigid support for the fixed and moving coils of the measuring element and provides a high degree of insulation between current carrying parts. The moving element or armature of the dynamometer (right) consists of two coils, mounted on a solid staff which carries the pen fork, restraining springs, damper vane and steel pivot. The pen element, shown in place, is easily taken out or replaced without tools*

hence, do not affect the scale characteristics nor the accuracy of the meter. The use of the molded frame also insures a high insulation value, making possible a dielectric test of 5000 volts, 60 cycles.

Both the stationary and moving coils are wound to predetermined contours and dimensions and are impregnated with insulating material. The moving coils are securely mounted on an insulated metal staff. The upper end of the staff passes through an annular guide bearing to receive the pen fork which carries the writing pen. The lower end carries a hardened and polished steel pivot which rests in a spring-mounted sapphire jewel. A damper vane moving in the field of two adjustable Alnico magnets is also mounted on the lower end of the staff.

Using stationary and fixed coils with suitable combinations of ampere-turns, five kinds of wattmeters are constructed:

Two-current Element AC
Three-current Element AC
Four-current Element AC
Two-current Element DC
Two-current Element AC-DC (Utility)

Speed of Response

The speed of response of the two-current element AC wattmeter, for various available degrees of damping, is illustrated in Fig. 4. These curves show the result of an instantaneous change in power from zero to 90% of full scale. It will be noted that standard damping is slightly heavier than critical and the pen completes its swing in about 1¼ seconds. The swinging time is approximately the same for any instantaneous change in power from one equilibrium point to another, regardless of whether these points are close together on the chart or are widely separated.

Fig. 6 shows the speed of response of the other four kinds of wattmeters. Standard damping on these meters is slightly less than critical and the pen completes its swing in about 1 second.

Wattmeters are normally supplied with the magnets set for standard damping as for most applications this gives the best results. Where a meter is supplied with standard damping and it is found necessary to change the response speed after the meter is in service, this can be readily accomplished by removing the chart drive and turning the two damper magnets to the desired position. If it is known in advance that other than standard damping is required for the application at hand, the magnets will be set for the desired value at the factory. With maximum damping the record is more nearly one representing average values of power. However, for the damping system to be effective in this manner, the frequency of the fluctuation must be about 1 cycle per second or higher.

Scales and Charts

All Model AW wattmeters use 4300 series charts, uniformly divided along the pen arc. **Portable recorders** should be scaled for the lowest self-contained range, usually 0-1 KW. The chart is then interpreted by multiplying any value read on the chart by a constant. On AC, this constant is the product of the current transformer ratio and the self-contained range corresponding to the potential tap used on the meter, and the ratio of the potential transformers (if used).

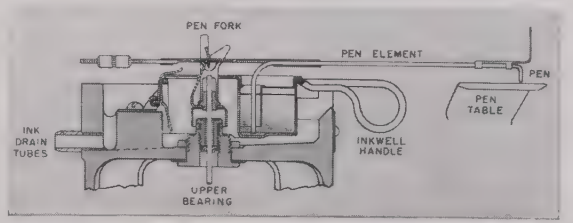


FIG. 3—*Cross sectioned view of the top of the measuring element frame, with inkwell and pen element in place, shows the canopy protecting the upper bearing, as well as the drain tubes that prevent spilled ink from reaching any current-carrying parts*

For example, assume a 100/200/500 volt, 5 ampere, 2-current-element AC wattmeter, calibrated 0-1/2/5 KW used on a 480 volt, 3-phase circuit with 200/5 CT's. The meter would probably have a 0-1 scale and chart. In this case, potential connections would be made to the 500 volt taps on the meter which

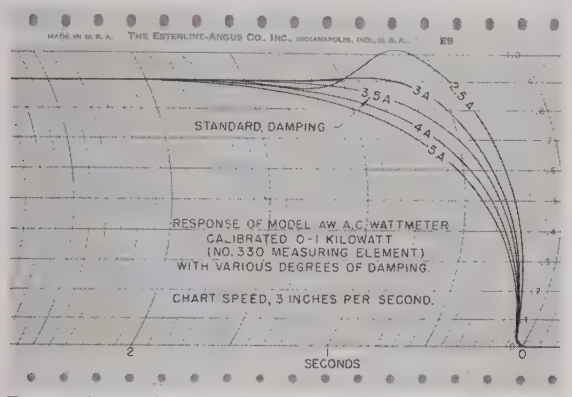


FIG. 4—*Speed of response is adjustable by setting the damping magnets at different points as shown. Standard damping of the two-current element AC wattmeter is approximately critical and gives a swinging time of about 1¼ seconds*

gives a multiplier of 5. The CT ratio is 40, so all readings on the chart would be multiplied by 200.

The same meter used on 2400 volts, 3-phase, with 2400/120 volt PT's connected to the 100 volt taps, and with 200/5 ampere CT's, would have a multiplier of 20 (PT ratio) x 40 (CT ratio) or 800.

On DC, full scale value is calculated by multiplying the shunt ratio by the potential tap multiplier, as discussed on page 10. For example, a 100/200 volt, 5 ampere, 100 millivolt DC wattmeter, calibrated 0-1/0-2 KW, and used on 250 volts, 2-wire with a 1000-ampere shunt, has a multiplier of:

$$\underset{\text{(Self-contained range of 200 volt tap)}}{2} \times \underset{\text{(Multiplying factor of shunt)}}{100} = 200.$$

Permanently mounted instruments are usually scaled in terms of total load. The full scale value is calculated in the same way as has been explained for portable meters. If the multiplying factor, and full scale value, happen to be some value, for which a chart is not printed, the wattmeter calibration can usually be altered to permit use of one of the direct-reading charts listed in Catalog Section 90.

An example will serve to make this process clearly understood. Suppose that an AC, 2-current-element wattmeter is to be connected on 3-phase, 3-wire, to 1200/5 ampere CT's and 2400/120 volt PT's. The "natural" scale of this meter is:

$$\underset{\text{(Self-contained)}}{0\text{-}1\text{ KW}} \times \underset{\text{(CT ratio)}}{240} \times \underset{\text{(PT ratio)}}{20} = 0\text{-}4800\text{ KW}$$

There is no standard chart having 0-4800 range numbers in the standard list, but there is a 0-5000 chart. Hence, the best calibration for this meter is 0-1041.7 watts, self-contained, (100 volts, 5.21 amperes full scale). From Table II on page 8, it is seen that this value is within allowable calibration limits.

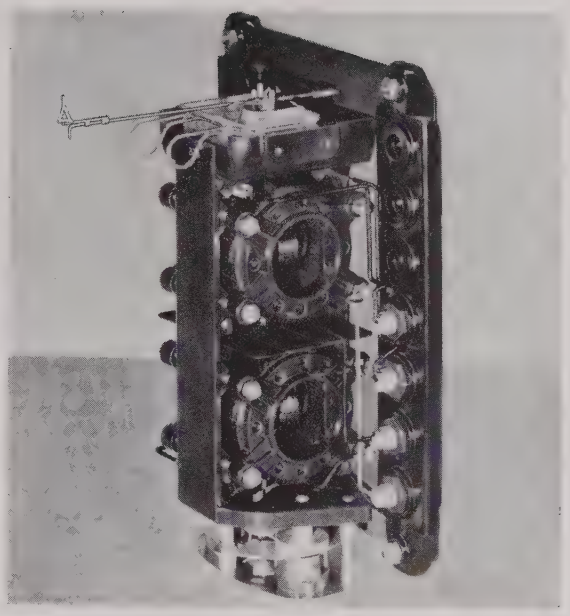


FIG. 5—*The electrodynamometer measuring element used in wattmeters ready for installation in a case. With its terminal blocks the measuring element is a unit and is interchangeable with other AW measuring elements*

Sometimes the natural scale matches a standard chart but it is desirable to depart from this value for other reasons. For example, assume that it is desired to put a wattmeter on a low power factor load. The voltage is 240 and 500/5 ampere CT's are already installed. The natural scale of this meter would be 0-200 KW with standard calibration of 0-2000 watts. However, we know that the load does not exceed 100 KW. The next higher value for which a standard chart is available is 0-120 KW. The meter would be calibrated 0-1200 watts (200 volts, 3.0 amperes full scale). Table II again shows that this is permissible.

Another type of installation in which it is desirable to depart from the natural scale is illustrated by some steel mill motors. Take the case of a mill motor rated with a full-load input of 1800 KW and operat-

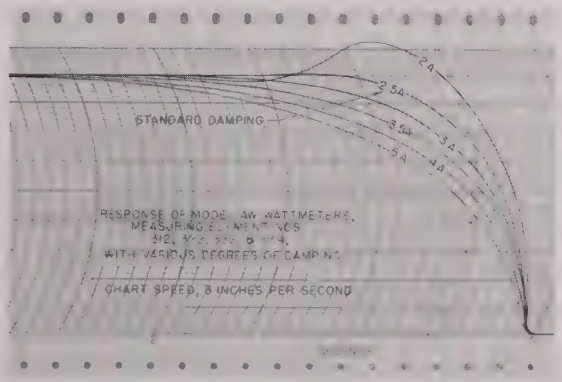


FIG. 6—*The combination of fixed and moving coils in these measuring elements results in a different setting of damping magnets for critical response, with a swinging time of about 1 second*

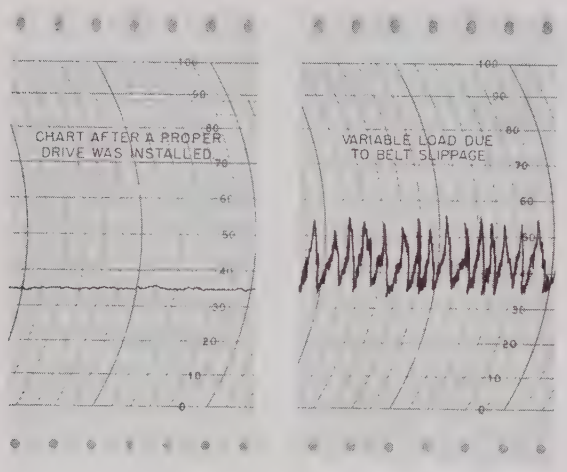


FIG. 7—*A 30 HP motor driving a blower overheated and wore out belts. The chart (right) shows excessive belt slipping. A 40 HP motor was installed, with a wider belt, and the chart at the left obtained*

ing from 60:1 PT's and 150/5 CT's. Also, suppose that this motor is designed to carry momentary overloads up to 50%. Actual power input may reach 2700 KW. The recorder should be scaled 0-3000 KW. To give the meter such a scale would require it to be calibrated for 0-1667 watts (100 volts, 8.33 amps). Table II shows that this calibration is beyond the limit for a 5-ampere meter so a 10-ampere instrument would have to be used to obtain the desired scale.

Each wattmeter is arranged so the user can place the zero at any point on the scale between the left-hand edge and center scale. Examples: When the zero is moved to the center of the scale a 0-1 KW recorder becomes ½-0-½ KW. Conversely, if a recorder originally furnished with calibration 1-0-1 KW has the zero shifted to the left hand edge, the range becomes 0-2 KW. The latter use may overload both the recorder and the current transformers.

Wattmeter vs. Ammeter

Frequently the decision must be made as to whether a wattmeter or an ammeter should be used for a particular job of recording.

For measuring the current on AC feeders, transformers or other electrical equipment where heating is the crux of the problem, the ammeter is the correct instrument to use. But for measuring work being done or the power load on different kinds of equipment, particularly AC motors or generators, the wattmeter should be used.

There are a number of reasons why this is true. In the first place, an ammeter in a motor circuit, for example, fails to give an accurate measure of the power load, because it does not take into account the applied voltage. If the voltage is below normal, a heavier current will flow, giving a false indication of the mechanical load on the machine. The wattmeter reads true power input, properly compensating for all values of both current and voltage from zero up to the capacity of the instrument and, on AC, for all changes in power factor.

In the second place, the characteristics of most types of AC motors are such that the current is not proportional to the load on the motor, even with voltage that is normal, due to the fact that the power factor varies with the motor load. Thus the *power* input to a squirrel cage induction motor carrying no load will usually be less than 10 per cent of the full load power, while the *current* will be anywhere from 25 to as much as 50 per cent of the full load current. It is evident, therefore, that current measurement gives a poor indication of the power when the motor is lightly loaded. The power varies over a much wider range than the current, and where load characteristics are desired, the wattmeter is the only instrument that will record them accurately.

Another advantage of the use of a wattmeter instead of an ammeter on AC motors is the behavior when the motor is started. The starting *power* seldom exceeds two or three times the full load power, and if the wattmeter range is such that full load power represents about two-thirds scale, the starting peak will not harm the instrument.

However, the starting *current* may be from three to eight times the running current, and since the torque developed by a dynamometer type ammeter is proportional to the square of the current, an ammeter may be subjected to as much as 50 times full scale torque when a motor is started under load. Repeated starting surges ultimately can result in damage to the instrument.

The choice between an ammeter and a wattmeter on DC is somewhat different. The DC wattmeter gives the better picture of the power load on a feeder, motor or generator, since it automatically takes into account variations in voltage. This is important on variable voltage circuits, such as the Ward-Leonard system on Diesel locomotives. However, if the system

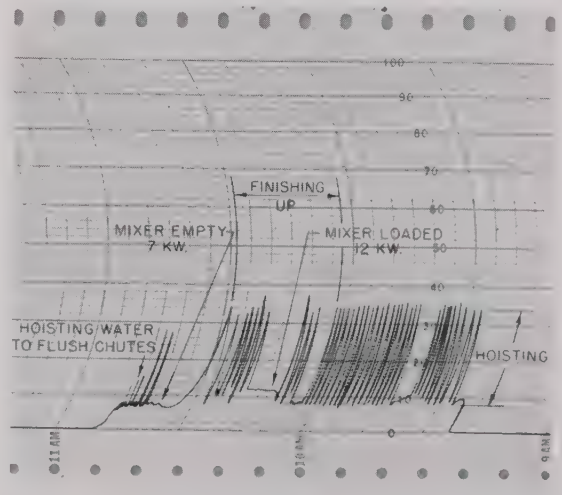


FIG. 8—*This chart shows the operation of a large gravity concrete-mixing plant. From the complete daily record the engineers can tell just how the plant is being handled*

is one where the voltage remains substantially constant, there is no appreciable difference between the record made by a DC wattmeter and a DC ammeter.

In applying permanently mounted DC meters, ammeters are often used where wattmeters would produce the better picture of circuit operating conditions. This is due to the fact that the current leads of DC wattmeters, which carry 5 amperes at full scale, and must be of very low resistance, are necessarily large. If the meter must be mounted some distance away from its shunt, as often happens in steel mill installations, the current leads become so large that they cannot be fastened to the meter terminals. So, where long leads are essential, the DC ammeter, which carries only 0.15 ampere in its leads, is frequently applied in place of the wattmeter. DC ammeter leads several hundred feet long are sometimes possible.

AC Wattmeters

Two-Current Element

The 2-current-element wattmeter is in effect, two single-phase wattmeters acting on a single staff. The two upper current coils together with the top moving coil on the staff form the "A" element in E-A nomenclature. The two lower current coils and the lower moving coil form the "B" element. The terminals of the recorders and all connection diagrams are marked A, A′, B, B′ to indicate clearly, both the elements and the terminals. The prime mark (′) indicates the instantaneous positive polarity. By connecting the two current coils of each element in series, inside the instrument, a 5-ampere, 2-current-element, meter is formed. Maximum current capacity is 7.5 amperes. When the line current exceeds the rated current of the instrument, or when used on circuits having voltage high enough to endanger the recorder or operator, current transformers must be used. When used on voltages in excess of self-contained range, potential transformers must be used. The transformers required for each type of AC wattmeter are shown on pages 8 and 9.

The two-element wattmeter can also be supplied with a 10 ampere or a special 20 ampere current rating. Maximum current carrying capacities are 15 and 25 amperes.

These two recorders are for use on an unchanging application where it is desired to measure current in the 10 or 20 ampere range without a current transformer. They cannot be successfully used with current transformers to measure currents exceeding their ranges.

Two-current element AC wattmeters are intended primarily for use on

Single phase, 2- or 3-wire, 25-60 cycles
2-phase, 3-, 4- or 5-wire, 25-60 cycles
3-phase, 3-wire, 25-60 cycles

* * *

Most three-phase, 4-wire star circuits can be measured with the 2-current element AC meter but a 3-current element meter is usually easier to apply.

Two- or 3-wire, DC circuits can also be measured with the 2-current element AC meter, within the self-contained range, but not with shunts.

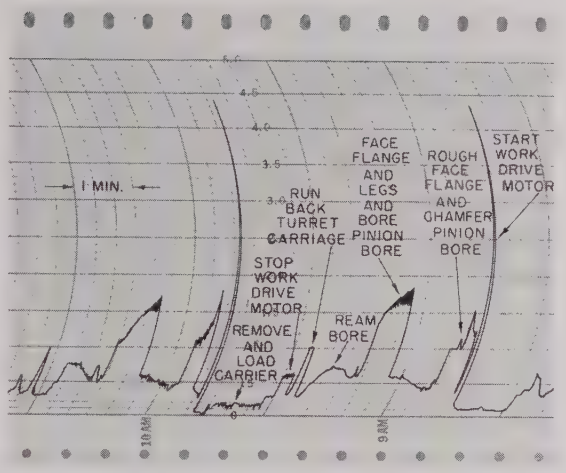


FIG. 9—*Part of a time study of six operations in boring and turning a differential carrier on a turret lathe. From the study of a nine hour chart the engineers specified tooling changes that saved two hours and twenty-four minutes*

Three-Current Element

This instrument, sometimes called a 2½ element meter, has three independent current circuits, for use on 3-phase, 4-wire. The third or "C" current circuit is obtained by connecting one of the top current coils in series with one of the bottom current coils and bringing out two terminals.

The accuracy of measuring 3-phase, 4-wire circuits with the 3-current element wattmeter is the same as using the 2-current element wattmeter with delta-connected current transformers, for any degree of current unbalance. The 3-current element wattmeter is usually easier to apply as it requires no interconnection of the current circuits.

Both instruments have a slight residual error under certain conditions of voltage unbalance. This error is ordinarily so small as to be negligible. Since there are two voltage circuits, two of the three branches of a three phase circuit are measured accurately. The third current, however, is reacted upon by the other two voltages to neutral. Hence, the unbalance error is that due to the amount the third voltage to neutral differs from the average of the other two voltages. **(Caution**—Burden of instrument is light causing inaccuracies with certain split-core current transformers.)

Four-Current Element

Four-current-element wattmeters have the terminals of all four current coils brought out to separate terminals. This meter is useful where the same instrument is to be used on all types of AC circuits. The current coils can be connected as in a 2- or 3-current-element meter, or they can be used independently. Each current coil will carry up to 12.5 amperes, although nominally calibrated for 5 amperes. On single phase with all four current coils in parallel, loads up to 5.0 KW at 120 volts can be handled without current transformers, the meter range being 0-10 KW. The 4-current-element watt-

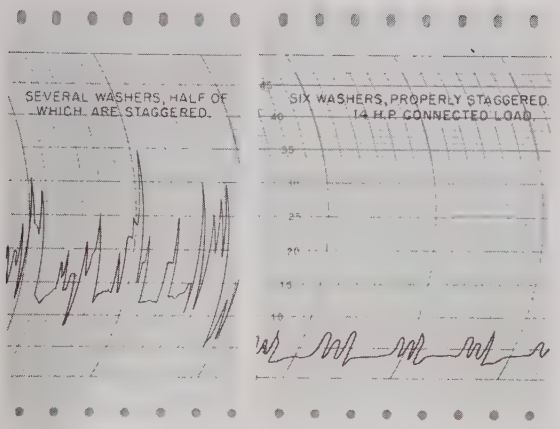


FIG. 10—*Washers in a commercial laundry produced the load record at the left with peaks as high as 36 KW. When six machines were staggered, the chart at the right was produced. 14 HP connected load requires only 8 KW peak*

meter will handle 3-phase, 4-wire, delta circuits, supplying combined light and power. (See diagram 11, page 11.) **(Caution**—Burden of instrument is light causing inaccuracies with certain split-core current transformers.)

DC Wattmeters

All wattmeters can be used on 2- or 3-wire DC up to their self-contained capacities. Only two, the DC and the AC-DC (Utility) wattmeter can be used with shunts. The current circuits of these two wattmeters are calibrated for 5 amperes, 100 millivolts at the shunt end of their calibrated current leads. Each current circuit, with its two five-foot current leads has a resistance of only 0.02 ohm. Any alteration of the length, wire size or even method of attachment of current leads will cause DC wattmeters to read incorrectly when operated from shunts.

An example will serve to show how sensitive wattmeter current circuits are to changes in resistance. Let us say that the standard five-foot current leads lack one foot of reaching from the recorder to its shunt. The standard leads are No. 4 wire. If one foot of No. 4 is added to each current lead, the resistance of each current circuit will become 0.02052 ohms, assuming no additional contact resistance. The meter will read 2.5% low. If the alteration is made with a smaller size wire, the effect becomes startling. If one foot of No. 14 wire is added to each lead, the total resistance of each current circuit then becomes 0.02524 ohm instead of 0.02 ohm. The meter will read 21% low, assuming the joints are good.

Shunts

DC wattmeter shunts are of two types, depending on whether the service is 2-wire or 3-wire. Two wire shunts divert 10 amperes through the wattmeter current coils at rated line current. (Diagram 5, page 11.) A 100-ampere shunt, therefore, produces 100 millivolts across its meter connection terminals with 90 amperes in the shunt and 10 amperes flowing through the meter, making a total line current of 100 amperes. To measure 3-wire DC, two shunts are required (diagram 6, page 11). Each shunt has one current circuit of the recorder connected across it. A 100 ampere, 3-wire shunt produces 100 millivolts across its meter connection terminals with 95 amperes in the shunt and 5 amperes through the meter. Refer to catalog section 80 for listing of E-A shunts.

Use with Miscellaneous Shunts

From the foregoing it is obvious that the use of DC wattmeters with shunts, other than those intended for the particular meter, presents a problem in calculating the resultant full scale value. The current diverted through the meter is an appreciable part of the line current up to a rating of 500 amperes for 3-wire and up to 1000 amperes for 2-wire shunts.

An example will show what can happen. Let us assume that it is desired to use a 50-ampere, 100-millivolt, DC *ammeter* shunt to operate a *wattmeter*. The ammeter shunt is calibrated to produce 100 millivolts across its meter connection terminals with 49.85 amperes in the shunt and 0.15 ampere diverted through the ammeter. Since the meter current is less than 1% of shunt rating, we can neglect it and consider that 50 amperes in the shunt produces 100 MV.

When used on 2-wire with a wattmeter, there will be 50 amperes in the shunt, 10 amperes diverted through the wattmeter, or a line current of 60 amperes at full load on the shunt. Hence, this shunt has a multiplier of 6 instead of 5. The error in the record is 16⅔% if the difference between a 50-ampere *ammeter* shunt and a 50-ampere *wattmeter* shunt is ignored. The lower the rating of the shunt, the greater the error will be. A 20 ampere, 100 millivolt ammeter shunt becomes a 30 ampere, 2-wire wattmeter shunt, which can result in an error of 33⅓%.

Similarly, 3-wire shunts may be used on 2-wire provided a correction is made. The 3-wire shunt normally diverts 5 amperes at full load but in 2-wire service 10 amperes will be diverted through the meter. Hence a 100 ampere, 3-wire shunt used on 2-wire should be considered a 105-ampere shunt.

Indicating instrument shunts, which are usually 50 millivolts, should not be used with left-hand zero, 100 millivolt wattmeters. The shunt will be fully loaded when the wattmeter reads about ½ scale. Since this situation does not appear alarming when looking at the record, shunts can be damaged without anyone realizing the danger until it is too late.

Center zero wattmeters, 50-0-50 millivolts, can be used on 50 millivolt indicating wattmeter shunts. They can also be used with 50 millivolt, indicating ammeter shunts if it is remembered that at full load on the shunt, the line current will be 5 amperes greater than the shunt rating. For example, a 50-0-50 MV, 2-wire, wattmeter comes to full scale on 5-0-5 amperes. A 50 ampere, 50 millivolt indicating ammeter shunt will produce 50 millivolts with 50 amperes in the shunt, since the current drawn by the indicating ammeter is negligible. Hence, at full load on the shunt, 50 amperes will flow in the shunt, and

5 amperes will be diverted through the meter. The effective range of the meter must be based on a shunt rating of 55 amperes.

AC-DC (Utility) Wattmeter

The AC-DC wattmeter is intended for interchangeable use wherever it is necessary to record either AC or DC power with the same instrument. It is identical with the DC wattmeter in having low resistance current circuits and is used on DC with shunts in the same way. Similarly, it is used on AC in the same manner as the two-current element AC meter. A compensating circuit in the AC-DC instrument makes it accurate even on low power factor loads. (**Caution**—Burden of instrument is light causing inaccuracies with certain split-core current transformers.)

Switching of Recorders to Two or More Circuits

For most cases where a recorder must be shifted from one circuit to another, standard instrument switches are available. It is not feasible to switch the current circuits of DC or AC-DC wattmeters operating from shunts. If the wattmeter being switched is operated from current transformers, the switch must be so constructed that the secondaries are never opened. One switch is required for each polyphase circuit to which the wattmeter is to be connected, but only one key should be provided, so two switches cannot be closed at any time.

Totalizing Power on Several Three-Phase Circuits

In many instances, it is desirable to record the total power on several circuits. There are a number of ways in which this can be done.

Three-Phase, Three-Wire Circuits

Assuming that the 3-phase voltages of the circuits being totalized are the same in magnitude, in phase and in synchronism, totalizing is usually fairly simple. If the current transformers on the several circuits all have the same ratio and there is no objection to paralleling secondaries of transformers on the same phase, the secondaries can be paralleled and brought directly to the current circuits of a 2-current element wattmeter, provided the desired scale is not too great. The recorder can be multi-range if desired to provide for adding one or more circuits in the future. The wattmeter potential circuits must be connected to one of the 3-phase circuits. Since they are all in phase and in synchronism, it usually makes no difference which one is chosen.

Where the range desired on the totalizing wattmeter exceeds the capacity of the wattmeter coils, it is possible to interpose auxiliary current transformers between the paralleled current transformer secondaries and the meter current coils. These auxiliary transformers are standard instrument current transformers with a single primary and a single secondary winding. In some instances where relays are

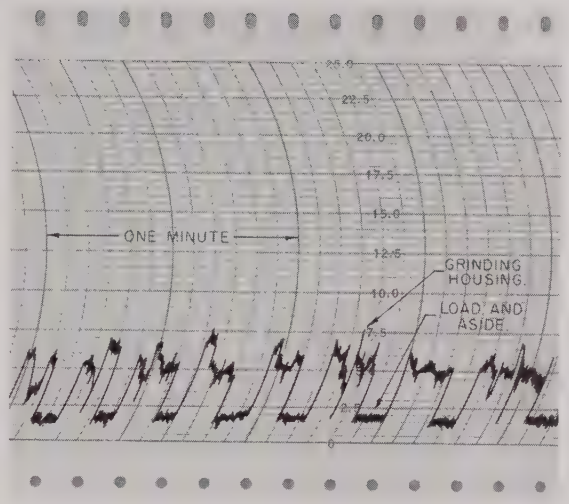


FIG. 11—*Chart, run at 3 inches per minute, in a time study of a grinding operation. Total time per piece varies from 13 to 19 seconds*

operated from the current transformers, there is objection to paralleling their secondaries. If there are only two circuits to be totalized, this can usually be done with the 4-current element wattmeter. The circuits can be totalized yet kept electrically separate in this instrument. It is also possible to totalize two such circuits by using a pair of current transformers each having two 5-ampere primaries and one 5-ampere secondary (3-wire transformers).

When the secondaries of current transformers cannot be paralleled and there are more than two circuits to totalize, two special current totalizing transformers must be used. These transformers have one primary winding for each 3-phase circuit to be totalized and have one 5-ampere secondary. They can be supplied with additional windings to provide for future addition of other circuits.

If the current transformer ratios on the circuits to be totalized are not alike, special totalizing current transformers must be used. The primary windings are designed to compensate for the different ratios on the several circuits. Provision can still be made for adding future circuits but the current transformer ratios on the future circuits must be known at the time the totalizing transformers are built.

Three-Phase, Four-Wire Circuits

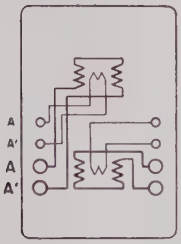
The problem of totalizing 3-phase, 4-wire circuits is similar to that of 3-wire. Usually a 3-current element wattmeter is required and three totalizing current transformers must be used.

If one or more of the 3-phase circuits to be totalized is separated from the others by power transformers or reactors, there will be some phase shift and some numerical difference in the voltage. It is sometimes possible to totalize such circuits with totalizing current transformers. Conditions can vary so widely that no definite rules can be set up as to when such totalizing is possible. It is best to correspond with the factory on all such applications.

Model AW Alternating Current Wattmeters

Two Current Element

For use on single phase, 2- or 3-wire; 2-phase, 3-, 4- or 5-wire; 3-phase, 3- or 4-wire, 25-60 cycles; and on DC within self-contained ranges.



2 Current, 2 Potential Circuits
Measuring Element No. 330

Kilowatts Self-Contained	Amps.	Volts
0-1.0	5	100
0-2.0	5	200
0-5.0	5	500
0-1.0/2.0	5	100/200
0-1.0/5.0	5	100/500
0-2.0/5.0	5	200/500
0-1.0/2.0/5.0	5	100/200/500

Overload — Potential circuits can be operated continuously 35% in excess of above rating. Current circuits will carry 7.5 amperes continuously.

Leads — Furnished only with portable type, 5 ft. long. Not calibrated.

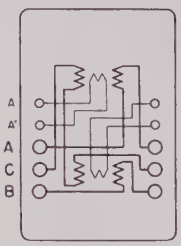
Current Transformers — Currents above 5 amperes:
Single Phase, 2 wire—1 CT
Single Phase, 3 wire—2 CT's
2 Phase, 3 or 4 wire—2 CT's
2 Phase, 5 wire —4 CT's*
3 Phase, 3 wire —2 CT's
3 Phase, 4 wire —3 CT's (Delta connected)
*Requires 10 ampere meter

Potential Transformers — For voltages beyond self-contained range:
Single phase, 2 wire—1 PT
2 Phase, 4 or 5 wire } 2 PT's connected
3 Phase, 3 wire } line-to-line
Single Phase, 3 wire } 2 PT's connected
2 Phase, 3 wire } line-to-neutral
3 Phase, 4 wire } line-to-neutral

Standard Ranges and Calibration Limits — See Table II

Three Current Element

For use primarily on 3-phase, 4-wire star circuits, 25-60 cycles. Can be used as a 2-element meter by disregarding the third current circuit. Consult factory for details.



3 Current, 2 Potential Circuits
Measuring Element No. 332

Kilowatts Self-Contained	Amps.	Volts
0-1.5	5	100
0-3.0	5	200
0-1.5/3.0	5	100/200

Overload — Potential circuits can be operated continuously 35% in excess of above rating. Current circuits will carry 12.5 amperes continuously.

Leads — Furnished only with portable type, 5 ft. long. Not calibrated.

Current Transformers — Currents above 5 amperes: 3 CT's required

(**Caution**—Burden of instrument is light causing inaccuracies with certain split-core current transformers.)

Potential Transformers — For voltages beyond the self-contained range, 2 PT's connected line to neutral.

Standard Ranges and Calibration Limits — See Table II

TABLE I—*Average Electrical Characteristics of left-hand zero 5A. 100 V. meter with 120 Volts applied and 5 Amperes in each current circuit.*

Meter	Circuit	Volts Across Current Terminals			Current Through Potential Coils (Amperes)			Burden (Volt-amperes)			Power Factor		Impedance (Ohms)		
		DC	25 cy.	60 cy.	DC	25 cy.	60 cy.	DC	25 cy.	60 cy.	25 cy.	60 cy.	DC	25 cy.	60 cy.
2 Element	Current	1.1	1.3	1.9	—	—	—	5.5	6.3	9.5	0.87	0.58	0.22	0.25	0.38
	Potential	—	—	—	0.057	0.057	0.057	6.8	6.8	6.8	1.00	1.00	2100	2100	2100
3 Element	Current[1]	0.16	0.18	0.28	—	—	—	0.8	0.9	1.4	0.85	0.60	0.03	0.04	0.06
	Potential	—	—	—	0.050	0.050	0.050	6.0	6.0	6.0	1.00	1.00	2400	2400	2400
4 Element	Current[2]	0.16	0.18	0.28	—	—	—	0.8	0.9	1.4	0.85	0.60	0.03	0.04	0.06
	Potential	—	—	—	0.037	0.037	0.037	4.5	4.5	4.5	1.00	1.00	3200	3200	3200

[1]Data apply to A and B current circuits. Burden of the C (split) current circuit is twice values shown.
[2]Data apply to each of the four current circuits.

TABLE II—*Nominal Ratings and Calibration Limits—Two and Three Current Element AC Wattmeters*

Calibration (warping) limits of wattmeters with nominal 5-ampere current circuit rating, using standard current and potential coil construction. Data are for a meter used on polyphase circuits without instrument transformers. If used with transformers, the scale range of the meter is the product of the self-contained range and the current and potential transformer ratios. If calibration higher than shown in the table below is required, use 10-ampere meter. Calibration limits are then double those shown; current circuits will carry at least 12.5 amperes each continuously.

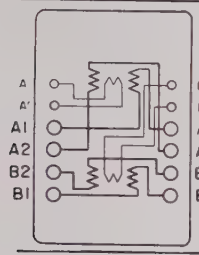
2-Current Element[3]			3-Current Element		
Nominal Ratings and Standard Ranges	Calibration Limits (KW)		Nominal Ratings and Standard Ranges	Calibration Limits (KW)	
	Minimum	Maximum		Minimum	Maximum
Left-hand zero					
100 Volts, 5 amps., 0-1.0 KW	0-0.5	0-1.25	100 Volts, 5 amps., 0-1.5 KW	0-1.2	0-3.0
200 Volts, 5 amps., 0-2.0 KW	0-1.0	0-2.5	200 Volts, 5 amps., 0-3.0 KW	0-2.0	0-6.0
500 Volts, 5 amps., 0-5.0 KW	0-4.0[4]	0-6.25			
Center zero					
100 Volts, 5-0 5 amps., 1.0-0-1.0 KW	0.25-0-0.25	1.25-0-1.25	100 Volts, 5-0-5 amps., 1 5-0-1.5 KW	0.6-0-0.6	3.0-0-3.0
200 Volts, 5-0-5 amps., 2 0-0-2.0 KW	0.5-0-0.5	2.5-0-2.5	200 Volts, 5-0-5 amps., 3.0-0-3.0 KW	1.0-0-1.0	6.0-0-6.0
500 Volts, 5-0-5 amps., 5.0-0-5.0 KW	2.0-0-2.0[4]	6.25-0-6.25			

[3]On single phase, 2-wire, with meter current coils in series, the ampere figures in the table remain the same, but the watts become ½ of those shown. On single phase, 2-wire with current coils in parallel (this connection should not be used with a current transformer) the watt figures in the table do not change but the amperes are twice those shown.
[4]By using an additional multiplier, minimum calibration is 2.5 amperes, 0-2.5 kw or 1.25-0 1.25 amperes, 1.25-0-1.25 kw. In many instances a 400 volt rating (usable up to 540 volts) is adequate, and can result in lower minimum ranges.

Model AW Alternating Current Wattmeters

Four Current Element

For use on any 1, 2 or 3-phase 25-60 cycle, circuit, including 3-phase, 4-wire delta circuits for combined light and power.



4 Current, 2 Potential Circuits Measuring Element No. 334

Kilowatts Self-Contained*	Amps.	Volts
0-1.0	5	100
0-2.0	5	200
0-5.0	5	500
0-1.0/2.0	5	100/200
0-1.0/5.0	5	100/500
0-2.0/5.0	5	200/500
0-1.0/2.0/5.0	5	100/200/500

*Nominal rating when connected as 2-current element meter on polyphase circuits.

Overload	Potential circuits can be operated continuously 35% in excess of above rating. Each current circuit will carry 12.5 amperes continuously.
Leads	Furnished only with portable type. A set of standard portable leads includes four, 5-foot potential leads, eight, 5-foot current leads and three, 12-inch jumper leads. Not calibrated.
Current Transformers	Where current will exceed 12.5 amperes per coil, use same number of CT's as for 2- and 3-current element meter. Diagrams page 10. (**Caution**—Burden of instrument is light causing inaccuracies with certain split-core current transformers.)
Potential Transformers	For voltage beyond the self-contained ranges, PT's are required, same as 2- and 3-current element recorders.
Standard Ranges and Calibration Limits	See Table III

2-, 3- and 4-Current Element AC Wattmeters

Charts—4300 Series, uniformly divided along pen arc. See catalog section 90.

Scales—To match any 4300 series chart. On multi-range wattmeters, the scale should match the lowest range or the range most used. Scale on permanently mounted meters should be chosen so that maximum loads to be recorded are below full scale value.

Zero—Normal calibration is for left-hand zero. The zero can be shifted to any point on the scale between the left-hand edge and center. See page 4.

Binding Posts—Can be furnished on portables, instead of leads.

Multipliers—Portable and flush recorders have multipliers mounted on back of case. Front switchboard and wall types have one separate standard size multiplier.

Damping—Adjustable magnets and damper vane.

Response Speed—See Figs. 4 and 6.

Dielectric Test—5000 volts, 60 cycles, for one minute.

Guaranteed Accuracy—1% of full scale watts.

Special Ratings—2 Element AC only: 10 ampere current coils can be furnished; 20 ampere current coils, measuring element No. 322, without leads or DC calibration also available. For ranges below standard limit or for use on 400 cycles, consult factory.

Shunts—Cannot be used with shunts but may be used on 2 and 3 wire DC circuits up to the self-contained ranges.

TABLE III—*Nominal Ratings, Standard Ranges and Calibration Limits—Four Current Element AC Wattmeter*

Data are for meter used without transformers. If used with transformers, the scale range of the meter is the product of the self-contained range and the current and potential transformer ratios. Each current coil will carry 12.5 amperes continuously.

Connected as a 2-Current Element Meter Current Coils of Each Element in Series, Diagram 7[5]			Corresponding Ranges when Connected as a 3-Current Element Meter, Diagram 9		
Nominal Ratings and Standard Ranges	Calibration Limits (KW)		Nominal Ratings and Standard Ranges	Calibration Limits (KW)	
	Minimum	Maximum		Minimum	Maximum
Left-Hand zero					
100 Volts, 5 amps., 0-1.0 KW	0-0.6	0-1.5	100 Volts, 5 amps., 0-2.0 KW	0-1.2	0-3.0
200 Volts, 5 amps., 0-2.0 KW	0-1.0	0-3.0	200 Volts, 5 amps., 0-4.0 KW	0-2.0	0-6.0
500 Volts, 5 amps., 0-5.0 KW	0-3.0	0-7.5	500 Volts, 5 amps., 0-10.0 KW	0-6.0	0-15.0
Center zero					
100 Volts, 5-0-5 amps., 1.0-0-1.0 KW	0.3-0-0.3	1.5-0-1.5	100 Volts, 5-0-5 amps., 2.0-0-2.0 KW	0.6-0-0.6	3.0-0-3.0
200 Volts, 5-0-5 amps., 2.0-0-2.0 KW	0.5-0-0.5	3.0-0-3.0	200 Volts, 5-0-5 amps., 4.0-0-4.0 KW	1.0-0-1.0	6.0-0-6.0
500 Volts, 5-0-5 amps., 5.0-0-5.0 KW	1.5-0-1.5	7.5-0-7.5	500 Volts, 5-0-5 amps., 10.0-0-10.0 KW	3.0-0-3.0	15.0-0-15.0

[5] When connected as shown in Fig. 8, all KW values are doubled.

Cases

Portable, wall, flush and front switchboard single cases are available and all but portable are also furnished in twin mounting. Flush cases have 120 volt, 60 cycle, fluorescent lighting. For certain other power sources, incandescent lighting can be furnished.

Chart Drives

Briefly, chart drives are divided into three general classes: hand-wound spring, motor-wound spring and synchronous. Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds of ¾, 1½ and 3 inches per second are obtained with external motor attachments.

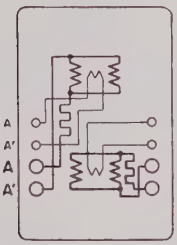
Model AW DC and AC-DC (Utility) Wattmeters

DC Wattmeter

For use on 2- or 3-wire DC circuits, with or without shunts. Nominal ratings up to 40 amperes, 2-wire and 20 amperes, 3-wire. Special calibrations without shunts can be furnished.

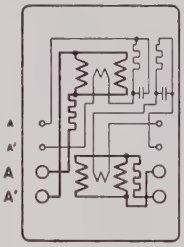
AC-DC (Utility) Wattmeter

For interchangeable use on AC, 25-60 cycles, and DC. The DC calibration and characteristics are the same as the DC wattmeter. They are used on AC in exactly the same manner as two element AC wattmeters, page 8.



2 Current, 2 Potential Circuits Measuring Element No. 322

Kilowatts Self-Contained	Amps.	Volts
0-1.0	5	100
0-2.0	5	200
0-5.0	5	500
0-1.0/2.0	5	100/200
0-1.0/5.0	5	100/500
0-2.0/5.0	5	200/500
0 1.0/2.0/5.0	5	100/200/500



2 Current, 2 Potential Circuits Measuring Element No. 312

Kilowatts Self-Contained	Amps.	Volts
0-1.0	5	100
0-2.0	5	200
0-5.0	5	500
0-1.0/2.0	5	100/200
0-1.0/5.0	5	100/500
0-2.0/5.0	5	200/500
0-1.0/2.0/5.0	5	100/200/500

TABLE V—*Average Electrical Data—DC and AC-DC Wattmeters*

Left-hand zero meter with standard 0-1000 watt calibration; 120 volts applied to potential circuits and 5 amperes in each current coil.

Circuit	Volts Across Remote End of Current Leads			Current Through Potential Coils (Amperes)	Burden in Volt-amperes			Power Factor		Impedance in Ohms		
	DC	25 cy.	60 cy.	DC, 25 or 60 cy.	DC	25 cy.	60 cy.	25 cy.	60 cy.	DC	25 cy.	60 cy.
Current	0.100[6]	0.12	0.17	——	0.500[6]	0.60	0.85	0.85	0.60	0.0200[6]	0.024	0.034
Potential	——	——	——	0.075	9	9	9	1.0	1.0	1600	1600	1600

[6]These are calibrated values and are exact. Other values are approximate.

Overload—Can be operated continuously with 25 amperes in each current circuit and potential up to 135/270/640 on the 100/200/500 volt ranges, respectively.

Charts—4300 Series. Uniformly divided along pen arc. See catalog section 90.

Scales—To match any 4300 series chart. On multi-range meters the scale should match the lowest or the most used range. On permanently mounted meters, the scale should be chosen so maximum values to be recorded are somewhat below full scale.

Zero—Normal calibration is left-hand zero. Can be shifted to center zero which cuts in half the current and watts to produce full scale deflection, Table VI. Center-zero meters can be shifted to left-hand zero without overloading the current circuits, unless original calibration was greater than 10-0-10 amperes, but may cause serious overloading of the shunt, if used.

Leads—Four 5-foot current and four 5-foot potential leads furnished with portables. Four 5-foot current leads furnished with other case styles. Current leads are part of the DC calibration and must be used when measuring with shunts. Standard, portable left-hand zero meters can be supplied with current leads up to 10-feet long and 15-feet in other case styles.

Binding Posts—Not permissible on current circuits when used with shunts. Without shunt, No. 8896 current binding posts can be used. No. 8897 potential binding posts can be used on portables.

Multipliers—Portable and flush types have multiplier mounted on back of case. Front switchboard and wall types have one separate, standard size multiplier.

Damping—Adjustable magnets and damper vane.

Response Speed—See Fig. 6.

Dielectric Test—5000 volts AC for one minute.

Guaranteed Accuracy—2% of full scale watts

Special Ratings—Special meters for voltage below 100, consult factory.

DC—Recorders for use on 2 wire only can be furnished. Only one potential circuit is brought out; four current and two potential leads are furnished. Usually used on high-voltage circuits having Ward-Leonard control, as on Diesel-electric locomotives, dredges and power shovels. Single-range meter with rating between 600 and 1200 volts (usable up to 800-1500 volts) can be supplied. Has one or two multiplier boxes, depending on voltage rating. Shunt must be in grounded side of service and meter case and separate multiplier case grounded. DC and AC-DC (Utility)—Calibration up to 20 amperes can be supplied.

Shunts—2-wire circuits, 1 shunt; 3-wire circuits, two identical 3-wire shunts. Normally, 100 MV shunts are used with 100 MV meters. Shunts having other drops can be used if allowance is made in calculating full scale value and precautions observed to prevent overloading shunts having less than 100 MV drop.

Current Transformers—AC-DC only, same as 2-element AC wattmeter, page 8. (**Caution**—Burden of instrument is light causing inaccuracies with certain split-core current transformers.)

Potential Transformers—AC-DC only, same as 2-element AC wattmeter, page 8.

TABLE VI—*Standard Ranges—DC and AC-DC Wattmeters*

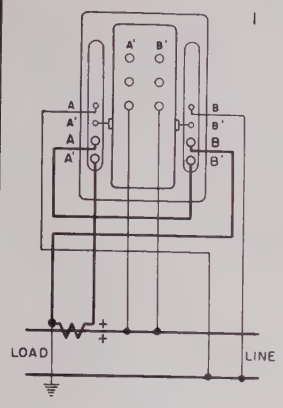
DC and AC-DC standard calibration of each current circuit is 100 MV at shunt end of leads at 5 amperes. When used with 100 MV shunt on 2-wire DC, the current circuits are connected in parallel and 10 amperes is diverted from the shunt through the meter. Scale range is the product of the self-contained range of the meter and 1/10 the ampere rating of the shunt. When used on a 3-wire DC system with two 100 MV shunts, 5 amperes is diverted from each shunt through the meter. Scale range is the product of the self-contained range of the meter and 1/5 the ampere rating of one shunt.

AC-DC meter used on AC with instrument transformers, scale range is the product of the self-contained range of the meter and the current and potential transformer ratios. MV data in the table are not applicable to meters used on AC.

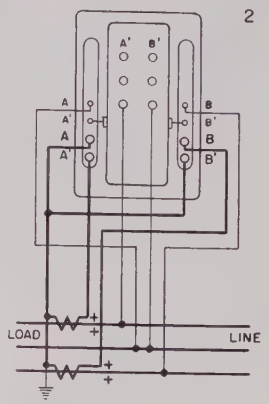
Zero Position	Nominal Rating					Range in KW (Self-contained)
	Potential Circuit Volts	Current Circuits				
		On 2-wire DC with current circuits in Parallel[7]		On 3-wire DC, 3 wire Single phase AC and polyphase AC		
		MV (on DC)	Amperes	MV (on DC)	Amperes	
Left-hand	100	100	10.0	100	5.0	0-1.0
Left-hand	200	100	10.0	100	5.0	0-2.0
Left-hand	500	100	10.0	100	5.0	0-5.0
Center	100	100-0-100	10-0-10	100-0-100	5-0-5	1.0-0-1.0
Center	200	100-0-100	10-0-10	100-0-100	5-0-5	2.0-0-2.0
Center	500	100-0-100	10-0-10	100-0-100	5-0-5	5.0-0-5.0

[7]Meter may be used on a 2-wire line with current circuits in series. When so used the amperes and self-contained KW are ½ those shown for the meter with current circuits in parallel. This connection should be used on a single phase circuit when a current transformer is employed.

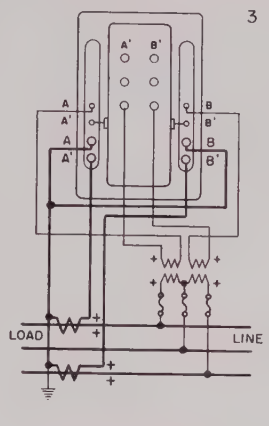
Most Used Connection Diagrams



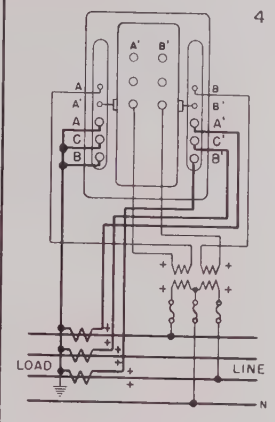
Two current element AC wattmeter on single phase, 2-wire circuit with current coils in series



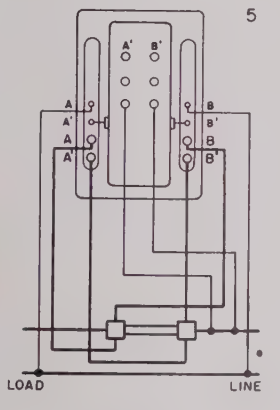
Two current element AC wattmeter on single or 2-phase, 3-wire circuit



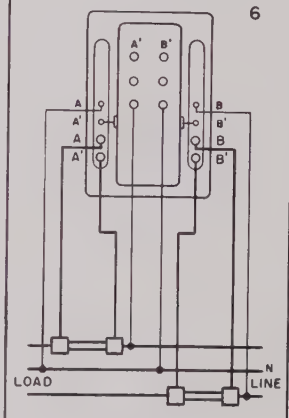
Two current element AC wattmeter on 3-phase, 3-wire circuit



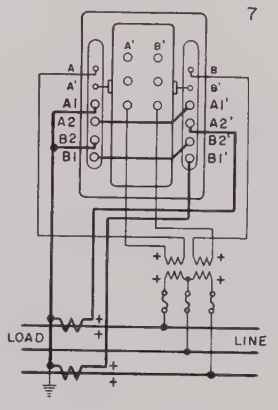
Three current element AC wattmeter on 3-phase, 4-wire star circuit



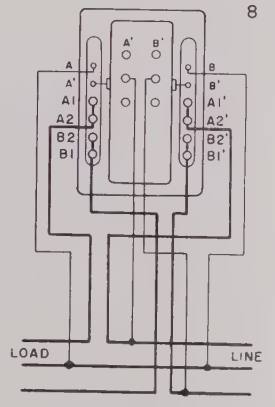
DC wattmeter on 2-wire DC circuit



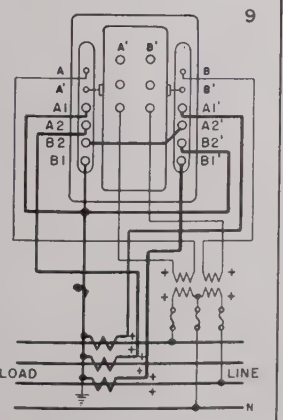
DC wattmeter on 3-wire DC circuit



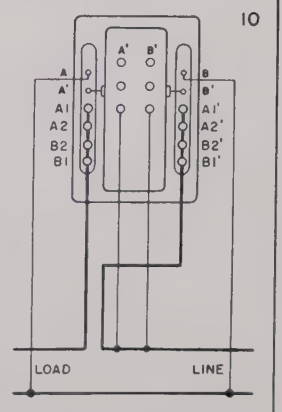
Four current element AC wattmeter on 3-phase, 3-wire circuit with current and potential transformers. Coils of each current element in series for 5 ampere range



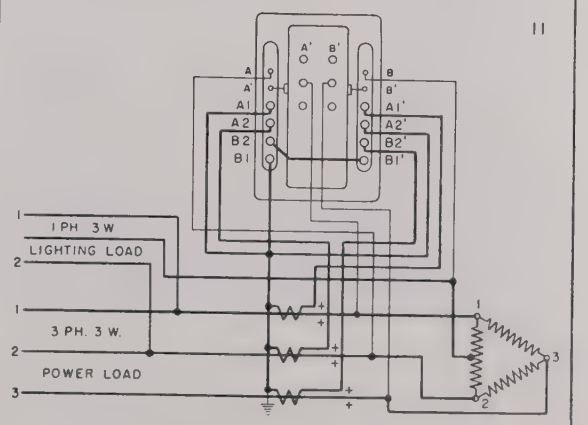
Four current element AC wattmeter on 3-phase, 3-wire circuit. Coils of each current element in parallel for 10 ampere range



Four current element AC wattmeter on 3-phase, 4-wire star circuit with current and potential transformers



Four current element AC wattmeter on single phase or DC, 2-wire circuit. Current coils in parallel for 20 ampere range



Four current element AC wattmeter used as three current element meter to measure combined power and lighting load on 3-phase, 4 wire delta circuit. The 200 volt tap on the meter is used and range is 0-2.0 KW self contained

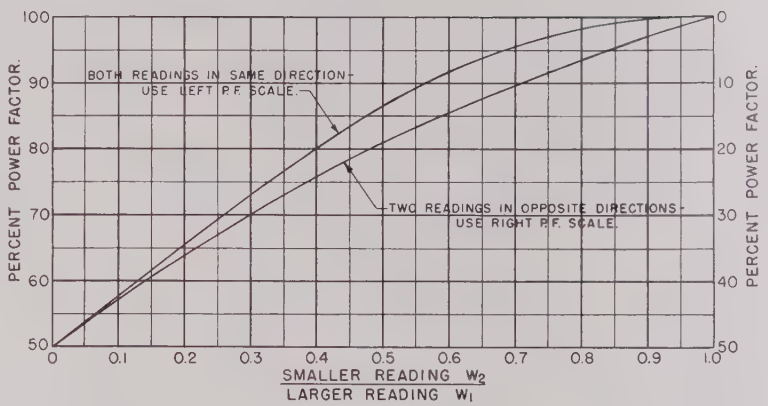
Reading Power Factor with a Wattmeter

Power Factor can be indicated with a 2- or 3-current element AC wattmeter on balanced 3-phase loads where the load is reasonably steady. This may be done with:

1—A 2-current element wattmeter connected as shown in diagram 3, page 11, on 3-phase, 3-wire.

2—A 2-current element wattmeter, on 3-phase, 4-wire, with delta-connected current transformers.

3—A 3-current element wattmeter connected as shown in diagram 4, page 11, on 3-phase, 4-wire.



First connect the wattmeter in the usual manner to record kilowatts. Then remove the connection from the "B" potential terminal on the meter, and observe the reading. Reconnect the "B" potential circuit, disconnect the "A" potential circuit and again note the reading. Except at unity power factor, one reading will be smaller than the other. Designate the smaller as W_2 and the larger as W_1. Divide W_2 by W_1.

When the power factor of the circuit is above 50%, both readings W_2 and W_1 will deflect the meter upscale (assuming a left-hand zero meter). With both readings in the same direction, the upper curve above determines the power factor from the ratio W_2/W_1.

If the power factor is below 50%, one of the readings will be down scale; the meter will deflect below zero. Reverse the potential connections temporarily to make the meter deflect upscale and note the value. Restore the original potential connections.

Then, divide the smaller, W_2, by the larger reading, W_1. With this ratio and the lower curve, the power factor can be determined.

At exactly 50% power factor, the reading of one element will be upscale and the reading of the other element will be zero.

How to Order—*Specify*

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall Mounting.

2—Chart Drive (Catalog Section 20): Hand-wound Spring, Motor-wound Spring, Synchronous. If electric, give voltage and frequency. If electric hour-to-minute feed shift desired, give voltage and frequency.

3—Measuring Element: Amperes, Volts, Millivolts. Left-hand or center zero. Number of phases, number of wires (not necessary on portables or general purpose instruments).

4—Scale and Chart (Catalog Section 90): Range numbers desired on chart and scaleplate. Chart speed.

5—Current Transformers (Catalog Section 80): Ratio, number used. Are we to furnish? Portable or switchboard.

6—Potential Transformers (Catalog Section 80): Ratio, frequency, number used. Method of connection. Are we to furnish? Portable or switchboard.

7—Shunts (Catalog Section 80): For 2- or 3-wire service? Portable or switchboard. Ampere rating (100 MV is standard for wattmeter shunts).

8—Leads: Length, if standard 5-foot leads cannot be used. Longer leads are possible for AC. DC and AC-DC meters are limited to 10-foot current leads with portables, 15-foot current leads with other case styles.

9—Accessories and Attachments (Catalog Section 80): Writing door, glass corner in case cover, chart inspector, carrying case, right- and left-hand chronograph pens (give voltage and frequency).

10—Supplies (Catalog Section 90): Extra pen elements, pen points, pen point cleaners, charts, ink.

THE ESTERLINE-ANGUS INSTRUMENT CO.

Pioneers in the Manufacture of Graphic Instruments

P. O. BOX 596, INDIANAPOLIS 6, INDIANA

ESTERLINE-ANGUS KVA and KVAR

Recorders

Analysis of System and Plant Loads

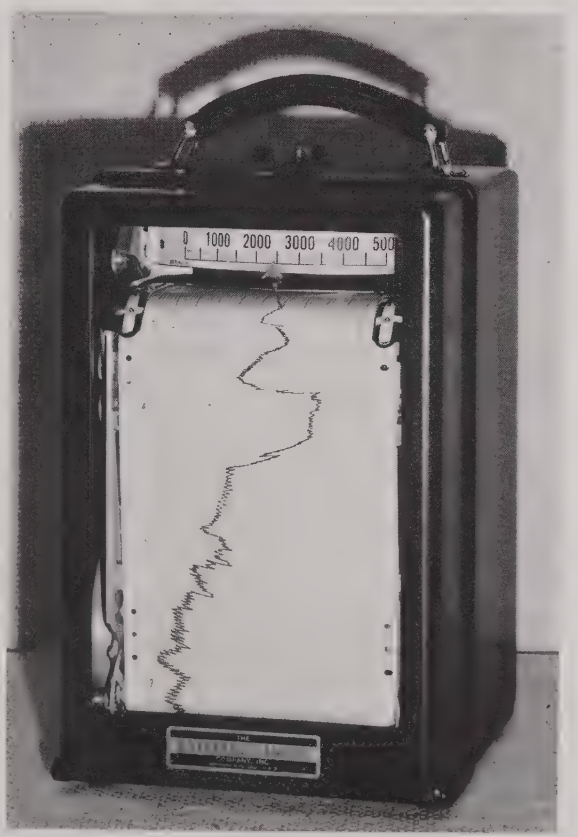
As electrical systems grow they tend to become unbalanced and have poor power factor. Analyzing all loads, feeders and transformer banks and reducing the "wattless" component of Kva is an economic necessity.

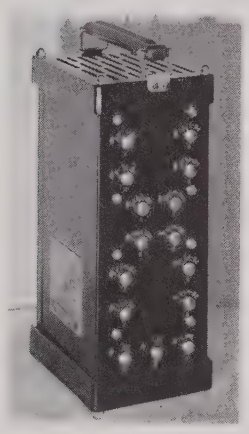
With These Simple Rugged Graphics

The method of measurement uses the familiar standard AC wattmeter, described in Catalog Section 33, and a phase shifting transformer to record either Kva or Kvar. This method should be used instead of power factor recorders, so both balanced and unbalanced loads will be measured properly.

Pays Both Industry and Utility

Equipment is operated more efficiently, line voltage is more uniform, cables, transformers and generators can carry more useful load when the ratio of Kw/Kva, (power factor) is raised to the highest value economically feasible.





KVA-KVAR Recorders Can Improve Plant Performance

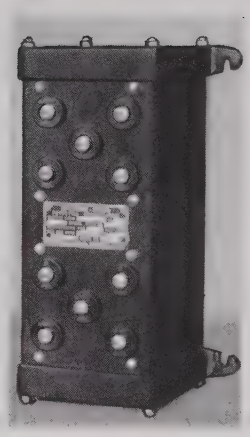


FIG. 1—*Model A phase shifting transformer, for both Kva and Kvar, shown in portable form, is also available for wall or switchboard mounting. It is usable up to 135 volts, 25 cycles or 270 volts, 50 or 60 cycles. The Model B transformer, for Kvar only, is somewhat smaller in size*

FIG. 2—*Double potential transformer, 240/480:120 volts, 50-60 cycles, is also available in portable form similar to the phase shifting transformer in Fig. 1*

IN ALTERNATING CURRENT CIRCUITS at unity power factor, volts times amperes equals watts input or work done. However, few AC circuits operate at unity power factor. In such instances volts times amperes equals volt-amperes, sometimes called the apparent power. The useful power in the circuit (watts) is some lesser value, depending on the power factor. The portion of Kva which does no useful work is called the reactive component or Kvar.

The cost of an electric system, either a utility system or an industrial plant system, depends on two factors which are entirely separate. First is the voltage at which the system will operate. This value determines the insulation level of all equipment and, therefore, has an important effect on its cost. Second, the current (amperes) that must be handled by the system determines the size of conductors used and affects the cost of generators, motors, transformers, circuit breakers and cables.

Hence, the investment cost of the system is more nearly proportional to Kva than to the Kw energy used. If Kva and Kw can be kept substantially equal (near unity power factor), the wattless component of power is small, line losses are reduced, and the system operates more efficiently. An example is shown in Figs. 3 and 5. The two sections of chart in Fig. 3 show the Kw and Kvar in a plant. In the period from 3:45 to 4:00 on the records, the average Kw load is 650, Kvar is 320 and Kva is 725. This represents a power factor of 90% which is usually considered to be quite high.

In Fig. 5 are two sections of chart showing the same load after a thorough study and power factor correction. As a result of the survey, the Kw load has been reduced to 500 in the same 15-minute period. The wattless component is substantially zero, so the power factor is unity. More useful load can now be carried without buying larger transformers, conductors, switches or circuit breakers.

Where the load consists of 3-phase motors, it is common practice to measure the true power with an AC wattmeter and the power factor with a power factor recorder. But, if single phase loads are added to the various phases, the system becomes unbalanced. A power factor recorder can no longer be used, for accurate studies, as it is essentially an instrument for balanced loads. Instead of measuring power factor directly it becomes necessary to use either Kw/Kva

$$\text{or} \quad \frac{\text{Kw}}{\sqrt{(\text{Kw})^2 + (\text{Kvar})^2}}$$

which is the ratio of true to apparent power. This value is considered the effective power factor of an unbalanced polyphase system.

There are two ways of measuring Kva and Kvar:

1—Recording voltmeters, ammeters and wattmeters with all charts synchronized, give all the data needed to calculate the ratio of true to apparent power. This method is not practical because of the large number of instruments required.

2—Use two graphic wattmeters, one of which is equipped with a phase shifting transformer to make it read Kva or Kvar. Loads with either balanced or unbalanced current can be measured with

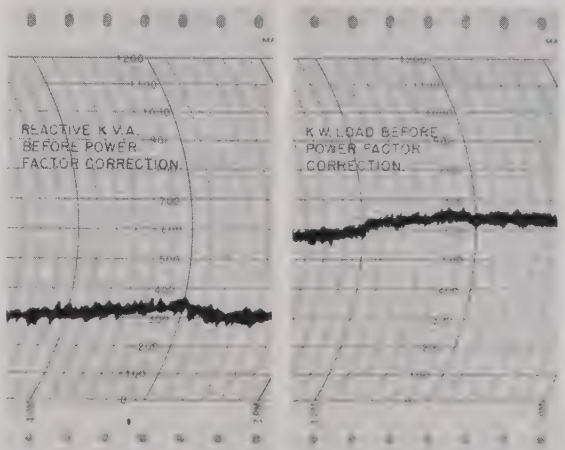


FIG. 3—*A plant load record of Kw and Kvar (reactive Kva) before power factor corrrection. The load in the period between 3:45 and 4:00 is at 90% power factor*

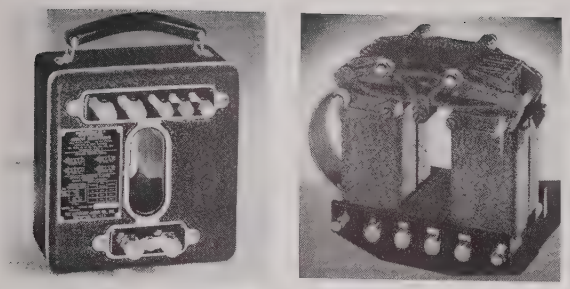


FIG. 4—*The versatility of portable Kva and Kvar recorders is greatly increased by using accessories designed to operate graphic instruments. The Model D Universal current transformer (left) has 7-primary ranges, 10-800 amperes. The split-core current transformer (right) is available in combinations of 3 ranges from 150 to 6000 amperes*

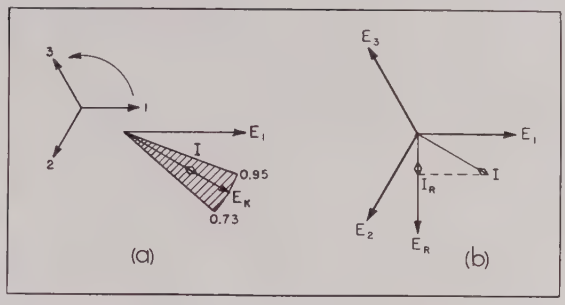


FIG. 6—(*a*) *shows the voltage band for the 0.73-0.95 tap of the phase shifting transformer. The power factor can vary between the limits of 73% and 95% without causing an error exceeding 1½% of Kva.* (*b*) *Using the same taps and one of the other phase voltages, Kvar can be measured at any power factor*

good accuracy, on systems having substantially balanced voltage. In general, the method using Kvar instead of Kva is recommended. Kvar measurements are completely independent of load power factor. A nomograph, Fig. 8 gives immediate knowledge of power factor, for any known values of Kw and Kvar.

Several variations of the second method are used by utilities for billing purposes. For certain loads it is sometimes possible to use two watthour meters, one reading watthours and the other varhours. These meters are read only at the regular meter reading period and an overall average power factor is calculated. Another method is to use integrating demand meters of the block interval type. This gives a better picture of extreme conditions because both Kw demand and Kvar at the time of the high demand can be determined.

Some utilities feel that neither of these methods gives the true picture of the customer's load and they have adopted E-A Kva recorders for demand billing on large loads. While it is too expensive for small loads, the E-A system provides the best method by which the customer can be shown just what happens to his load and power factor 24 hours a day throughout the billing period. The exact 15-minute interval in which demand was established can be picked from the record, and the chart is available for re-examination if desired. We know of one utility using Kva demand billing that has a unique way of handling customer complaints about the demand charge. They give the customer the record and ask him to pick his own 15-minute demand. It has been their experience that the customer invariably comes out with a higher demand charge than the one shown on his bill.

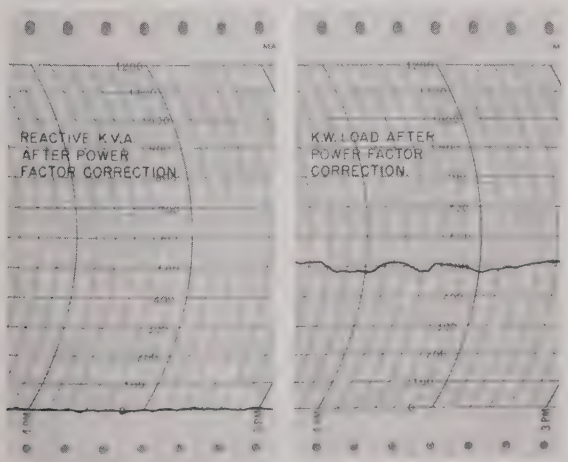


FIG. 5—*After thorough load study and power factor correction, the load in Fig. 3 was reduced to 500 Kw at approximately unity power factor, releasing 225 Kva to handle additional load*

The industrial plant engineer has all of the same measurement methods open to him but he is usually interested in the second method because of the simplicity. Knowledge of when the peak occurred, how it built up, and how often, will show him how he can reduce the demand charge, lower system investment and operate more efficiently.

To record Kva with a wattmeter, a phase shifting transformer is interposed between the line and the wattmeter. This phase shifting transformer supplies, to the potential circuits of the wattmeter, a voltage which lags the line potential by an amount equal to the lag of the line current behind the line potential. This creates the equivalent of unity power factor conditions in the meter, so it reads Kva instead of Kw. The use of this principle permits rather wide swings of load power factor before objectionable errors in the measurement of Kva are introduced.

The Model A phase shifting transformer provides three different voltages for making these measurements. It has three sets of taps for power factor in the ranges of 0.53-0.85, 0.64-0.93 and 0.73-0.95. Taking the 0.73-0.95 set of taps as an example, a wattmeter whose potential circuits are connected to these taps will read Kva. From Fig. 7 the maximum inaccuracy due to the transformer between 0.73 and 0.95 PF is 1½%. To this error must be added the guaranteed accuracy of the wattmeter which is ± 1%. Hence, within this power factor band, the combination of wattmeter and phase shifting transformer will record Kva so that the maximum inaccuracy will never exceed 2½% and may be as low as ½%. This is shown by the simple vector diagram in Fig. 6 (a).

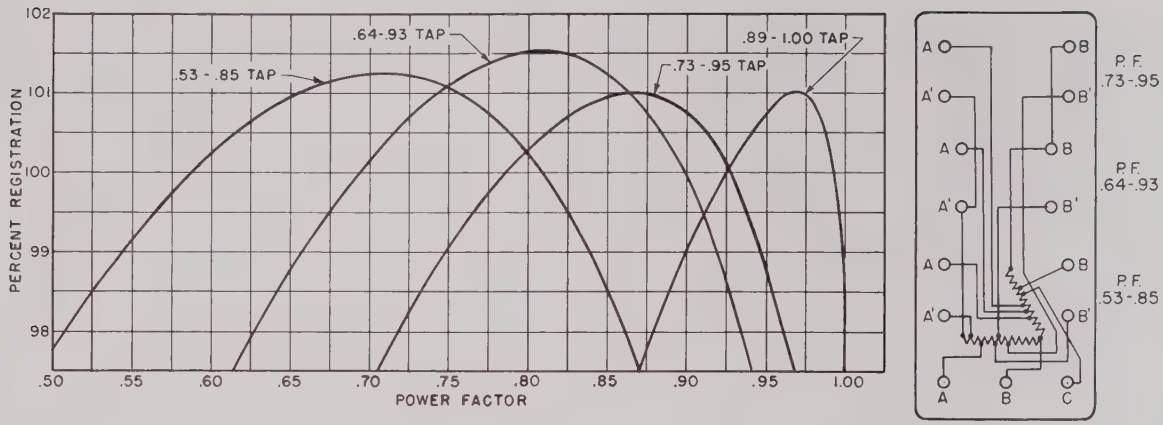


FIG. 7—*Accuracy curves of the phase shifting transformer on each set of taps show that a wide band is covered by each tap. The Model A transformer with three taps is usually used and its internal connections are shown at the right. The fourth tap is required only with certain recorders used for Kva demand billing where the power factor is known to be above 90%*

Assume a 3-phase system with phase rotation 1-2-3. Let E_1 be the voltage of one phase and I, the current produced by that voltage. On its 0.73-0.95 tap, the phase shifting transformer produces voltage E_K which is applied to the wattmeter potential circuits. Even if the current I swings to the 0.95 limit or to the 0.73 limit, readings of Kva are still within 1½% of correct value. The same reasoning applies to the other sets of taps on the phase shifting transformer.

If the power factor falls outside the limit for each set of taps, readings will always be low, never high. This error is usually of no consequence as it normally occurs at times of light load. When more accurate records at the extreme end of a power factor band are desired, the potential connections can be shifted to the set of taps containing the actual power factor. A special Model A transformer having a fourth set of taps, marked 0.89-1.00 is also available.

Similarly, a wattmeter will record vars if a voltage is applied to its potential coils that is 90° from normal. This can be done using the same Model A transformer mentioned above, or the Model B transformer (rated for 120 volts 60 cycles, and for var measurements only). Fig. 6 (b) is a simple vector diagram showing how var measurement is accomplished. In this figure we have the same voltage E_1 producing current I and we want to measure the product of the wattless component I_R and a voltage E_R at 90° to E_1. The phase shifting transformer produces the voltage E_R of the same magnitude as E_1, and lagging 90°. A meter which reads watts when operated from voltage E_1 reads vars when operated from voltage E_R. Readings are independent of load power factor.

continued on page 8

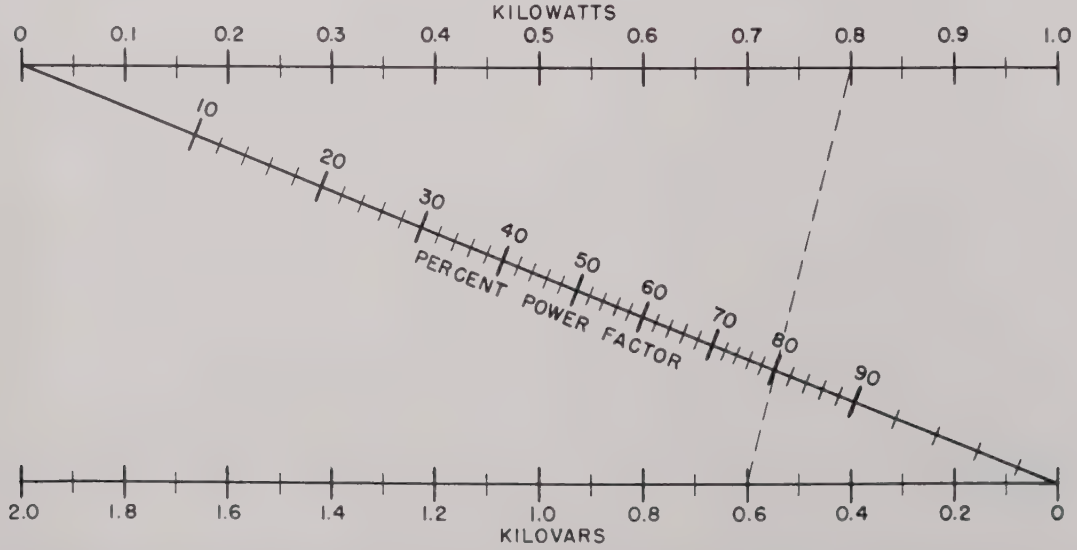
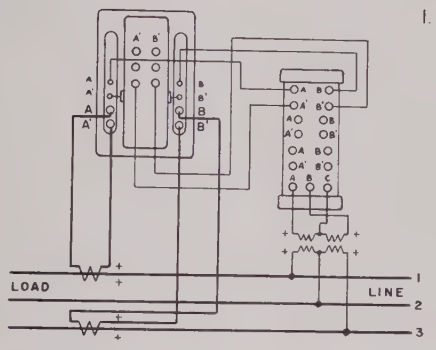


FIG. 8—*This convenient nomograph makes it easy to determine power factor when Kw and Kvar are known. Simply lay a straight edge from the Kw value to the Kvar value, as shown by the dotted line. Where this line intersects the power factor scale, read power factor of the circuit. To use values not shown on the Kw and Kvar scales, both scales can be multiplied by the same factor 10, 100 or 1000*

Typical Kva and Kvar Connection Diagrams

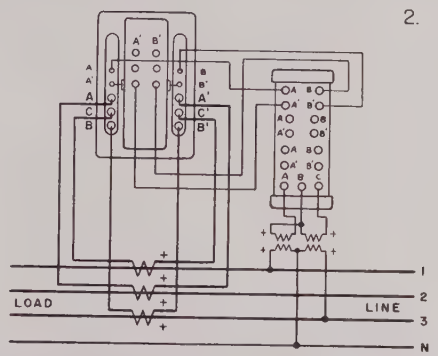
All diagrams are for phase rotation 1-2-3, lagging power factor. In all diagrams showing 2-, or 3-current element AC wattmeters, the 4-current element recorder can also be used. All phase shifting transformers shown are Model A

1.



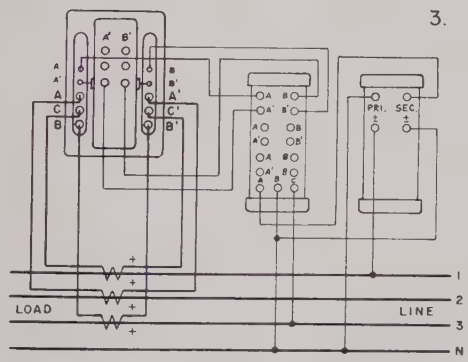
Kva measured with a 2-current element AC wattmeter, phase shifting transformer, current and potential transformers on 3-phase, 3-wire

2.



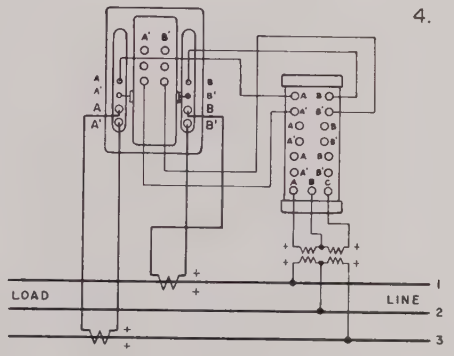
Kva measured with a 3-current element AC wattmeter, phase shifting transformer, current and potential transformers on 3-phase, 4-wire

3.



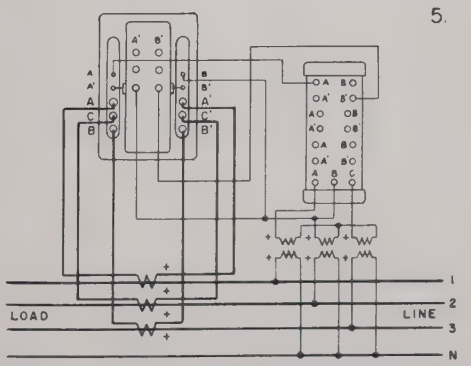
Kva measured with a 3-current element AC wattmeter on 120/208 volts requires an isolating potential transformer

4.



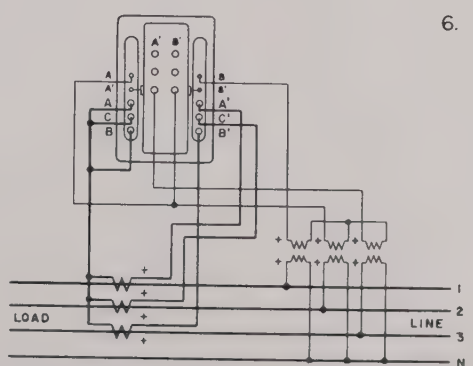
Kvar measured with a 2-current element AC wattmeter, phase shifting transformer, current and potential transformers on 3-phase, 3-wire

5.



Kvar measured with a 3-current element AC wattmeter, phase shifting transformer, current transformers and star-connected potential transformers on 3-phase, 4-wire

6.

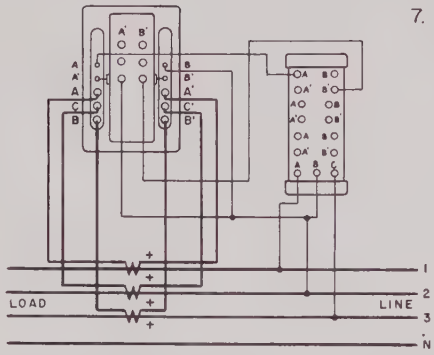


Kvar measured with a 3-current element AC wattmeter, current transformers and star-connected potential transformers on 3-phase, 4-wire, without phase shifting transformer (Special meter calibration required)

Typical Kvar and Kw-Kvar Connection Diagrams

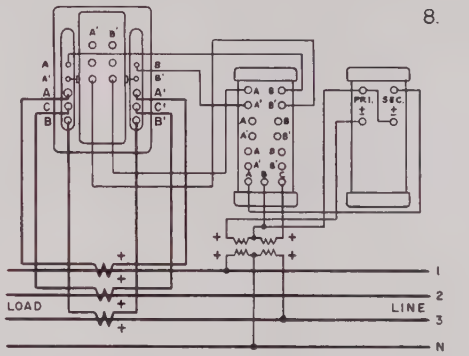
All diagrams for phase rotation 1-2-3, lagging power factor. In all diagrams showing 2-, or 3-current element AC wattmeters, the 4-current element recorder can also be used. All phase shifting transformers shown are Model A

7.



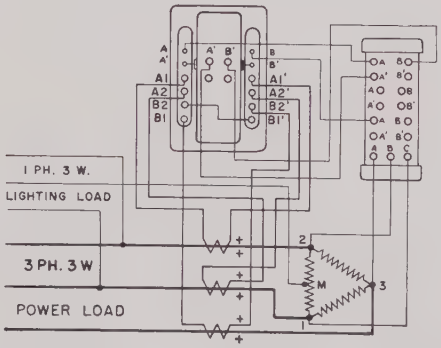
Kvar measured with a 3-current element AC wattmeter on 120/208 volts with a phase shifting transformer and current transformers

8.



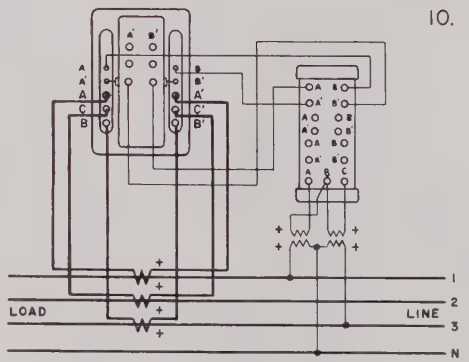
Kvar measured with a 3-current element AC wattmeter, phase shifting transformer, current and 2 potential transformers, connected line-to-neutral, requires an isolating transformer if the potential transformer secondaries have like polarities connected together

9.



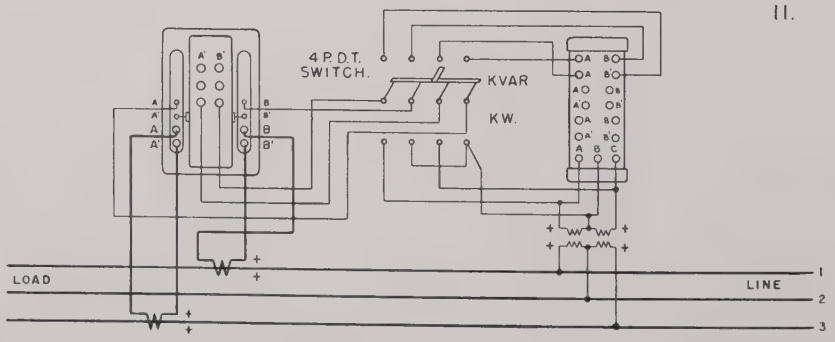
A 4-current element AC wattmeter with a phase shifting transformer will measure **Kvar** on 3-phase, 4-wire delta (240 V.), and 120/240 volts single phase lighting combined. This diagram shows the instrument connected as a 3-current element meter

10.



Kvar measured with a 3-current element AC wattmeter, with current transformers, but with the potential transformer secondaries not interconnected, does not require the isolating transformer shown in diagram 8

11.



Kw-Kvar connections for 3-phase, 3-wire using a single meter and 4 PDT switch. The switch can be motor driven if desired

Model AW, Kva and Kvar Recorders

AC Wattmeter and Phase Shifting Transformer. Wattmeters use measuring element No. 330 (2-current element), 332 (3-current element) or 334 (4-current element). See Catalog Section 33.

KVA Recorders

For 3-phase, 3-wire and 3-phase, 4-wire, 25-60 cycle circuits, where power flow is in a single direction. If power flow can reverse, use center-zero wattmeter and varmeter.

Type	KVA Self-Contained	Amps	Volts
2-Current Element	0-1.0	5	100
	0-2.0	5	200
	0-1.0/2.0	5	100/200
3-Current Element	0-1.5	5	100
	0-3.0	5	200
	0-1.5/3.0	5	100/200
4-Current Element	0-1.0	5	100
	0-2.0	5	200
	0-1.0/2.0	5	100/200

Calibration Limits—Nominal ratings are shown above. For calibration limits, see Tables II and IV, catalog section 33.

Zero—Same characteristics as 2-, 3-, or 4-current element AC wattmeter. See Catalog Section 33. Center-zero KVA recorders are not usable on most circuits. Where power flow can reverse, recordings should be made with center-zero AC wattmeter and center-zero varmeter. On tie lines, where power factor can be either lagging or leading a center-zero varmeter should be used with a center-zero wattmeter to interpret the records.

Dielectric Test—Recorder only, 5000 volts 60 cycles, for one minute. Phase shifting transformer only, 2500 volts, 60 cycles, for one minute.

KVAR Recorders

For 3-phase, 3-wire and 3-phase, 4-wire, 25-60 cycle, circuits. When flow of vars can reverse, use center-zero meter. Two phase, 3-, 4- or 5-wire can be measured with a wattmeter alone.

Type	KVAR Self-Contained	Amps	Volts
2-Current Element	0-1.0	5	100
	0-2.0	5	200
	0-1.0/2.0	5	100/200
3-Current Element	0-1.5	5	100
	0-3.0	5	200
	0-1.5/3.0	5	100/200
4-Current Element	0-1.0	5	100
	0-2.0	5	200
	0-1.0/2.0	5	100/200

Guaranteed Accuracy—Wattmeter only, 1% of full scale. Combined accuracy of recorder and Model A Transformer measuring Kva is 2½% within the marked power factor bands. The accuracy of var measurements is 2½% of full scale using Model A and 1½% using Model B transformer and is independent of power factor.

Charts, Scales, Leads, Binding Posts, Multipliers, Damping, and Response Speed are same as corresponding AC wattmeter. See Catalog Section 33.

TABLE I—*Average Electrical Burden, KVA and KVAR Recorders with Nominal Rating, Model A Network at 120 Volts, 5 Amperes*

	Circuits	25 Cycles				60 Cycles			
		Volt-Amperes	Volts	Current (Amperes)	Power Factor	Volt-Amperes	Volts	Current (Amperes)	Power Factor
2-Current Element	Current	6.3	1.3	5.0	0.87	9.5	1.9	5.0	0.60
	Potential	10.0	120	0.083	1.00	8.4	120	0.073	1.00
3-Current Element Current data apply to A and B current circuits. Burden of C current circuit is twice value shown.	Current	0.9	0.18	5.0	0.85	1.4	0.28	5.0	0.60
	Potential	9.0	120	0.073	1.00	7.5	120	0.062	1.00
4-Current Element Current data apply to each of the four current circuits.	Current	0.9	0.18	5.0	0.85	1.4	0.28	5.0	0.60
	Potential	7.5	120	0.071	1.00	6.0	120	0.060	1.00

TABLE II—*Current and Potential Transformers Required for KVA and KVAR Measurements with Wattmeter and Phase Shifting Transformer*

Circuit	Recorder Portable instruments should be equipped with 100 and 200 volt potential taps for maximum flexibility.	Current Transformers for currents above self-contained range	Potential Transformers,[1] if voltage above 135 V. 25 cy. or 270 V. 50-60 cy. KVA	KVAR
			Model A Phase Shifting Transformer Required.	For permanent installation on 120 V. 60 cy. use Model B phase shifting transformer. For all other purposes, use Model A.
3-phase, 3-wire	2-Current Element.	Two	Two See diagram 1.	Two See diagram 4.
	4-Current Element, connected as 2-Current Element meter.			
3-phase, 4-wire	2-Current Element.	Three (delta-connected)	Two PT's, Line-to-Neutral Reversed secondary potential is required. If other devices are operated from the PT's, an isolating PT may be required. See diagram 2. Three PT's, Star Use only Line-to-Neutral from two PT's, per note above and diagram 2. Isolating PT (120:120) is required on 120/208 V. to provide necessary reversed potential. See diagram 3.	Two PT's, Line-to-Neutral Reversed secondary potential is required. If other devices are operated from the PT's, an isolating PT may be required. See diagrams 8 and 10. Three PT's, Star—See diagram 5. No PT's—See diagram 7. In diagrams 5 and 7, Line-to-Line potential is applied to the phase shifting transformer, but 100 V. taps on wattmeter are used.
	4-Current Element, connected as 2-Current Element meter.			
	3-Current Element.	Three		
	4-Current Element connected as 3-Current Element meter.			
3-phase, 4-wire Delta combined light and power. 240 V., 3-phase; 120/240 V. single phase	2-Current Element with 200 V. potential circuits.	One single and one double primary (3-wire) CT or 3 CT's, one having one-half the rating of the other two.		No PT's—See diagram 9.
	4-Current Element with 200 V. potential circuits, connected as 2-Current Element.			
	4-Current Element with 200 Volt potential circuits.	Three identical CT's.		

[1]On 480 volt circuits. E-A double potential transformer can be used.

TABLE III—*Current and Potential Transformers Required for VAR Measurement Without Phase Shifting Transformer*

Circuit	Recorder Portable instruments should be equipped with 100/200/500 V. potential circuits for maximum flexibility.	Current Transformers for currents above self-contained range.	Potential Transformers
3-phase, 4-wire	2-Current Element.	Three (delta-connected)	Above 480 V.—2 PT's Requires special calibration of meter or use of an odd multiplying factor. See diagram 6.
	4-Current Element connected as 2-Current Element meter.		
	3-Current Element.	Three	
	4-Current Element connected as 3-Current Element meter.		
2-phase, 3-, 4- or 5-wire	2-Current Element.	3- or 4-wire—Two CT's 5-wire—Four CT's and 10-ampere meter; or two 3-wire CT's and 5-ampere meter.	Above 480 V.—2 PT's
	4-Current Element connected as 2-Current Element meter.		
	4-Current Element.	Four	

Potential Transformers

For convenience in use, the Model A transformer is designed for connection to either 100 or 200 volt potential taps on a wattmeter. On 480 volt circuits, a double potential transformer, Fig. 2, is supplied to be used with either the Model A or Model B transformer and wattmeter. For higher voltages, any good potential transformers may be used.

If potential transformers are already installed, like polarities of their secondaries will generally be connected together. (See pages 5 and 6.) It is usually not possible to reconnect them. If reversed potential for the phase shifting transformer is necessary for the proposed method of measurement, it is then obtained by using a 120:120 volt isolating transformer. The number of transformers required for various types of circuits is shown in Table II.

Types of Wattmeters Used

Kva and Kvar measurements can be made using 2-, 3- or 4-current element AC wattmeters, which are described in catalog section 33. On all applications requiring only a 2-current element meter, the AC-DC wattmeter can also be used. The choice of the meter to use depends entirely on the variety of work to be done. For 3-phase, 3-wire, requiring only a 2-current element meter, the simpler 2-element instrument should be used, either AC or AC-DC. The 3-current element meter (or a 4-current element meter connected as 3 element) should be used on 3-phase, 4-wire service. Where it is desired to handle special situations or to use the same recorder interchangeably on 3-phase, 3- or 4-wire, the 4-current element meter should be selected, since it is the most versatile of all the wattmeters. (See the connection diagrams on pages 5 and 6.)

Without Phase Shifting Transformer

Two-phase Kvar measurements can be made with a standard 2-element wattmeter and no phase shifting transformers, since the phase voltages are naturally at 90° to each other. Kvar measurements can also be made on 3-phase, 4-wire circuits without a phase shifting transformer but the wattmeter must be specially calibrated. Permanently installed varmeters are often used in this manner. Current and potential transformer requirements are shown in Table III.

Cases

Portable, wall, flush and front switchboard single cases are available and all but portable are also furnished in twin mounting. Flush cases have 120 volt, 60 cycle, fluorescent lighting. For certain other power sources, incandescent lighting can be furnished.

Chart Drives

Briefly, chart drives are divided into three general classes: hand-wound spring, motor-wound spring and synchronous. Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds of ¾, 1½ and 3 inches per second are obtained with external motor attachments.

How to Order—*Specify*

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall Mounting.

2—Chart Drive (Catalog Section 20): Hand-wound Spring, Motor-wound Spring, Synchronous. If electric give voltage and frequency. If electric hour-to-minute shift desired, give voltage and frequency.

3—Measuring Element: Amperes, Volts, Frequency, Type of Circuit—3-phase, 3- or 4-wire.

4—Scale and Chart (Catalog Section 90): Range numbers desired on chart and scale. Chart speed.

5—Current Transformers: Ratio. Switchboard or portable. Are we to furnish?

6—Potential Transformers: Ratio. Frequency. Switchboard or portable. Number used and how connected. Are we to furnish?

7—Phase Shifting Transformer: Switchboard or Portable. Model A or B?

8—Accessories and Attachments (Catalog Section 80): Writing door, glass corner in case cover, chart inspector, carrying case, right- and left-hand chronograph pens (give voltage and frequency).

9—Supplies (Catalog Section 90): Charts, extra pen elements, pen points, pen point cleaners, ink.

THE ESTERLINE-ANGUS COMPANY, INC.

Pioneers in the Manufacture of Graphic Instruments

P. O. BOX 596, INDIANAPOLIS 6, INDIANA

Catalog Section 35
Printed in U. S. A., 10M

Product Representatives
in Most Principal Cities

ESTERLINE-ANGUS
Power Factor
Recorder

Single and Three Phase

Low Power Factor

—Robs both utility and industrial plant of capacity
—Causes lower voltage and operating efficiency
—Increases maintenance
—Requires larger conductors to carry the load

Correction Is possible By

—Surveying the load
—Using continuous recording
—Rearranging motors to load them fully
—Installing synchronous motors operating at unity or leading power factor
—Installing static condensers

Using Power Factor Recorders

—Can show the way to improved electrical system efficiency
—Can lead to reductions in capital investment and operating costs

Catalog Section 37
(January 1957)

Model AW Power Factor Recorders

Crossed-Coil Electrodynamometer Measuring Elements

AS COSTS of labor and material continue to increase, the benefits of efficiency in operation, application and use of equipment increase correspondingly. Neither the utility nor the industrial plant can afford to put in excess copper, an extra large generator or a bigger transformer to handle today's load, when part of that capacity represents waste due to low power factor. To the utility it represents capacity that brings in no revenue. To the industrial plant engineer it means larger feeders, larger transformers, low voltage and overheating of motors, high maintenance and inefficient operation.

The power factor recorder is one of the tools to use in finding out what conditions exist on each system or load. Then, corrective action can be taken that will pay dividends to both user and utility. Since the causes of low power factor exist at the point of use, the biggest dividends result from improvement at that point.

An intensive study to operate all motors as near full load as possible, to show where synchronous motors are justified, and to locate the load points to be corrected by static condensers, pays off in reduced power bills, better voltage regulation and lower maintenance. Synchronous motors or static condensers involve expenditures for capital equipment, but quite often it is found that the first solution involves only the shifting of motors from one machine to another to accomplish one-half to two-thirds of the possible power factor improvement.

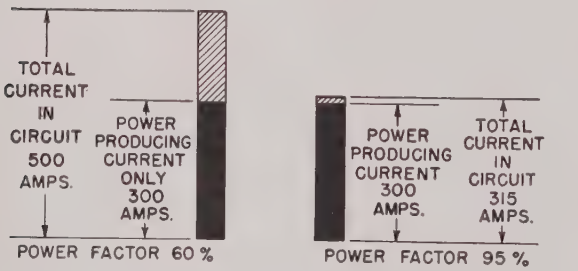

TOTAL CURRENT IN CIRCUIT 500 AMPS.
POWER PRODUCING CURRENT ONLY 300 AMPS.
POWER FACTOR 60 %
POWER PRODUCING CURRENT 300 AMPS.
TOTAL CURRENT IN CIRCUIT 315 AMPS.
POWER FACTOR 95 %

FIG. 1—*The meaning of power factor and how much "wattless" current can be flowing in the plant distribution system is illustrated above. The same amount of useful work is done in both examples*

Power Factor Recorders Are Simple

For many years, power factor recorders were limited to three phase and there was no single instrument to measure single phase power factor. Now the E-A line includes both single and three-phase types; an inductance box to adapt the single phase instrument to three phase use is also available. Both meters use the crossed-coil dynamometer measuring element, similar in construction to that used in AC ammeters, voltmeters and wattmeters. In the power factor recorders, the stationary coils of the dynamometer measuring element are energized from a current circuit. Usually this circuit is rated 5 amperes full load but may be supplied for 10 amperes. The moving coils of the metering element are in the potential circuit of the instruments.

Continued on page 4

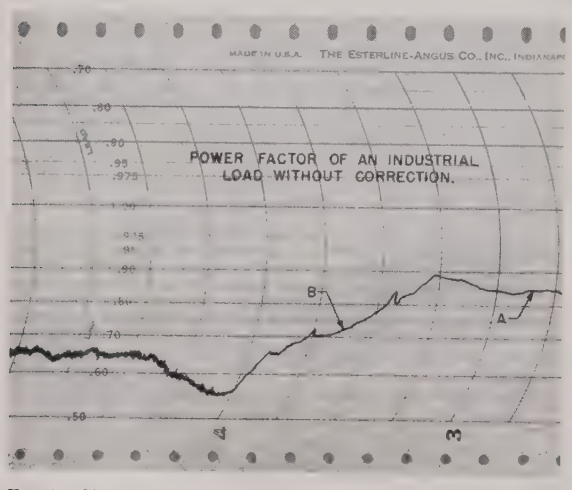


FIG. 2—*Chart of the power factor in a large industrial plant having a connected load of several thousand horsepower of induction motors. At "A" when the load was mostly lighting, the power factor was 0.85 but decreased as the induction motors were started (B)*

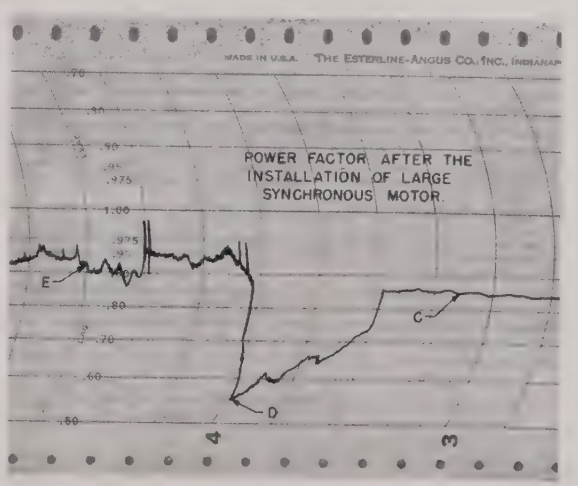


FIG. 3—*In the same plant as Fig. 2, a department needing DC installed a synchronous motor-generator set. Chart shows the lighting load "C", the induction motors on "D" and the improvement in power factor "E" made by the synchronous motor*

Model AW Power Factor Recorders

Single Phase—*Measuring Element No. 350*
Frequency—60 Cycles Only

Rating	
Amperes	Volts
5	120
5	240
5	480
5	120/240
5	120/480
5	240/480
5	120/240/480

Meter has one current and one potential circuit and is for use primarily on single phase where direction of power flow is the same at all times.

Separate inductance box converts meter for 3-phase operation. Must be calibrated with recorder.

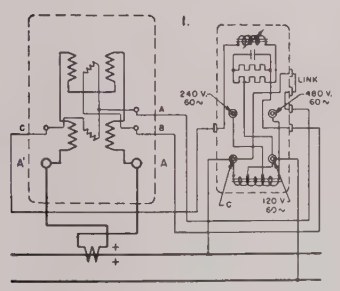
Three Phase—*Measuring Element No. 350*
Frequency—25 to 60 Cycles

Rating	
Amperes	Volts
5	120
5	240
5	480
5	120/240
5	120/480
5	240/480
5	120/240/480

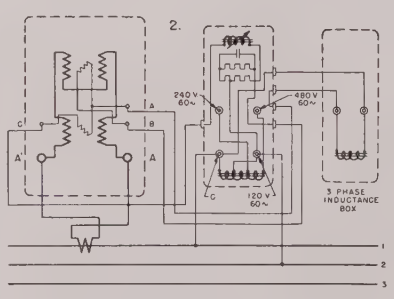
Meter has one current and two potential circuits and is for use on *balanced* 3-phase, 3-wire or 4-wire circuits where power flow is always in the same direction. For unbalanced loads use wattmeter and KVAR recorder.

Average Electrical Characteristics. 120 Volt, 5-Ampere Recorder at 5 Amperes, 120 Volts

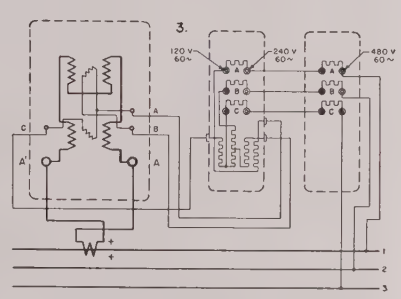
Circuit	Volts Across Current Terminals		Current Thru Potential Coils		Burden in VA		Power Factor		Impedance in Ohms	
	25 cy.	60 cy.	25 cy.	60 cy.	25 cy.	60 cy.	25 cy.	60 cy.	25 cy.	60 cy.
Single Phase										
Current		3.8				19		0.58		0.76
Potential				0.225		27		1.00		530
Three Phase										
Current	2.5	3.8			12.5	19	0.87	0.58	0.5	0.76
Potential			0.125	0.125	15	15	1.00	1.00	1000	1000



Connections for single phase recorder



Connections for single phase recorder with 3-phase inductance box on 3-phase, 3-wire circuit



Connections for 3-phase recorder on 3-phase, 3-wire circuit

Charts—No. 1407, See chart list 355 or catalog section 90. Non-uniform, expanded at unity PF.

Scale—0.50 lag-1.00-0.70 lead, to match chart No. 1407

Zero—Meter has no torque springs and, therefore, has no free zero and no zero adjuster. Pen will remain at any point when power is disconnected.

Capacity—5 ampere current coils will carry 7.5 amperes continuously. 120, 240 and 480 volt taps are usable on 100-135, 200-270 and 400-540 volts, respectively.

Leads—Furnished with portables (5 feet) and twin wall meters (3 feet). Longer leads are possible.

Binding Posts—Can be furnished with portable meters.

Multipliers—Single Phase—Portable and flush meters have deep-style multiplier box attached to case back. Other cases use separate multipliers. Three phase inductance box is standard size and separate. Three Phase—Portable and flush meters with one or two voltage ranges have attached standard size multiplier. An additional separate multiplier is required for a third voltage range. Other case styles have separate standard size multipliers, one for single and double voltage ranges, two for triple voltage meters.

Damping—Critical with rated voltage and current applied. Adjustable magnet and damper vane type.

Response Speed—Time required for pen to complete swing one way, 1.2 second with rated voltage and current applied.

Dielectric Test—Single Phase, 2500 volts, 60 cy., for one minute; Three phase, 5000 volts, 60 cy., for one minute.

Guaranteed Accuracy—Single Phase, 1½% and three phase, 1% of scale width with rated voltage applied and 2 amperes or more in the current circuit.

Special Rating—Can be furnished with 10-ampere current circuit, maximum capacity 15 amperes.

Current Transformers—One CT required when current exceeds 5 amperes. Select with primary rating as low as possible for greater accuracy on light loads.

Potential Transformers—On voltages over the self-contained ranges, one PT required for single phase recorder. For 3-phase recorder, two PT's are required on 3-phase, 3-wire circuits. On 3-phase, 4-wire circuits the meter may be fed from two PT's connected line-to-line or three PT's connected line-to-neutral. Latter connection requires a 240 volt range on recorder.

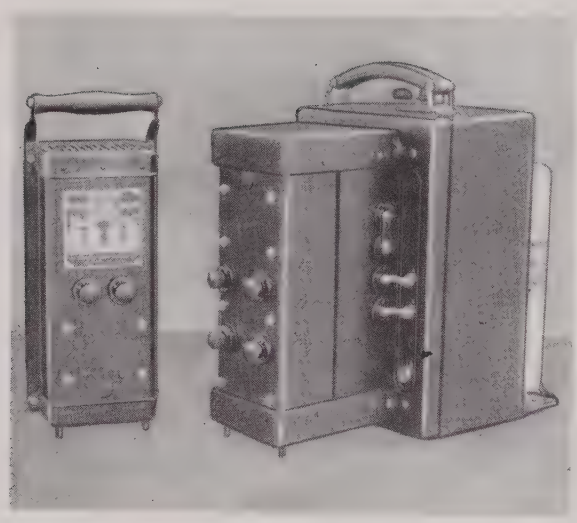


FIG. 4—*Portable single-phase power factor recorder can be converted to three-phase with separate inductance box illustrated above. The separate box is connected where the link appears on the side of the attached multiplier box.*

Continued from page 2

The moving element of either style of recorder has no torque springs and no free zero. The pen will remain at any point on the scale when power is disconnected.

The single phase recorder has a link connector on the multiplier box that is closed for single phase use, as in diagram 1, page 3. The link is opened when a three-phase inductance box is connected to convert the recorder to three-phase operation. (diagram 2)

Three phase recorders are designed for three-phase, three-wire and four-wire balanced circuits only. Three-phase, four-wire balanced circuits can also be handled by the single-phase recorder, with its potential circuit connected line to neutral to read power factor in one leg of the Y. Power factor of unbalanced loads can best be measured with a wattmeter and KVA or KVAR recorder.

Current transformers should be selected so that the current in the current coils will be two amperes or more. Lower currents will result in lower torque and reduced accuracy. Power flow must always be in one direction unless provisions are made to reverse the current coil connections when the power reverses. Current coils rated at 5 amperes will carry 7.5 amperes continuously without overheating. A special 10-ampere instrument is also available, having a maximum continuous current-carrying capacity of 15 amperes.

A single scale *0.50 lag-1.00-0.70 lead* is available and chart No. 1407 matches this scale. The three-phase recorder can be used on 25, 50 or 60 cycles but the single phase meter is available only for 60 cycle service.

Cases

Portable, wall, flush and front switchboard single cases are available and all but portable are also furnished in twin mounting. Flush cases have 120 volt, 60 cycle fluorescent lighting.

Chart Drives

Briefly, chart drives are divided into three general classes: hand-wound spring, motor-wound spring and synchronous. Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds of ¾, 1½ and 3 inches per second are obtained with external motor attachments.

How to Order

Specify

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall Mounting.

2—Chart Drive (Catalog Section 20): Hand-wound spring, Motor-wound spring, Synchronous. If electric give voltage and frequency. If electric hour-to-minute shift desired, give voltage and frequency of shift coil.

3—Measuring Element: Amperes, Volts, Single Phase, 3-phase, 3-wire or 3-phase, 4-wire. If single phase, is 3-phase inductance box desired?

4—Current Transformer: Ratio. Are we to furnish? Switchboard or portable.

5—Potential Transformers: Ratio. Frequency. Switchboard or portable. Number used and how connected. Are we to furnish?

6—Chart Speed.

7—Accessories and Attachments (Catalog Section 80): Writing door, glass corner in case cover, chart inspector, carrying case, right- and left-hand chronograph pens (give voltage and frequency).

8—Supplies (Catalog Section 90): Extra pen elements, pen points, charts, ink.

THE ESTERLINE-ANGUS COMPANY, INC.

Pioneers in the Manufacture of Graphic Instruments

P. O. BOX 596, INDIANAPOLIS 6, INDIANA

Catalog Section 37
Printed in U. S. A., 10M

Product Representatives
in Most Principal Cities

ESTERLINE-ANGUS Model AW Frequency *Recorders*

IN THESE DAYS of inter-connected power systems, the direct-writing, E-A frequency recorder is used on large systems to show performance under major fault conditions. Having 10 cycles or more spread across its chart, it is useful in making an immediately available record of serious frequency disturbances. In isolated plants and on small systems, this frequency recorder is often the only frequency instrument in the plant. It serves as the performance record for the small station and from this record the condition of governor equipment and handling by the operator can be observed. Frequency recorders are also widely used in the performance testing of small portable diesel-electric generating units. They are frequently used as speed recorders with rather highly suppressed zero. For example, a small alternator can be connected to a 60 cycle frequency recorder scaled in terms of speed rather than frequency.

The direct-writing frequency recorder uses a crossed-coil, electrodynamometer measuring element, similar to that used in AC ammeters, voltmeters and wattmeters described in catalog sections 30 and 33. It has no restraining springs and, therefore, no free zero. The pen remains stationary when power is disconnected. All frequency recorders are rated 120 volts and may be operated on 100-135 volts. Variations in voltage affect the torque and, consequently, the speed of response. For best performance, the operating voltage should be maintained near the rated value. Series multipliers are available for 240, 480 and 240/480 volts. On higher voltages, potential transformers are used with the 120 volt range of the recorder.

The measuring system consists of two series resonant circuits. One is tuned to a frequency near the low end of the scale and the other to a frequency near the high end. Wave form, if badly distorted, affects the reading slightly and an adjustment is provided for making this correction.

Chart Drives

Briefly, chart drives are divided into three general classes: hand-wound spring, motor-wound spring and synchronous. Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds of ¾, 1½ and 3 inches per second are obtained with external motor attachments.

How to Order—*Specify*—

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall Mounting.

2—Chart Drive (Catalog Section 20): Hand-wound spring, Motor-wound spring, Synchronous. If electric give voltage and frequency. If electric hour-to-minute feed shift desired, give voltage and frequency.

3—Measuring Element: Voltage. Frequency.

4—Scale and Chart: Range numbers desired on chart. Chart speed.

5—Accessories and Attachments (Catalog Section 80): Writing door, glass corner in case cover, chart inspector, carrying case, right- and left-hand chronograph pens (give voltage and frequency).

6—Supplies (Catalog Section 90): Extra pen elements, pen points, charts, ink.

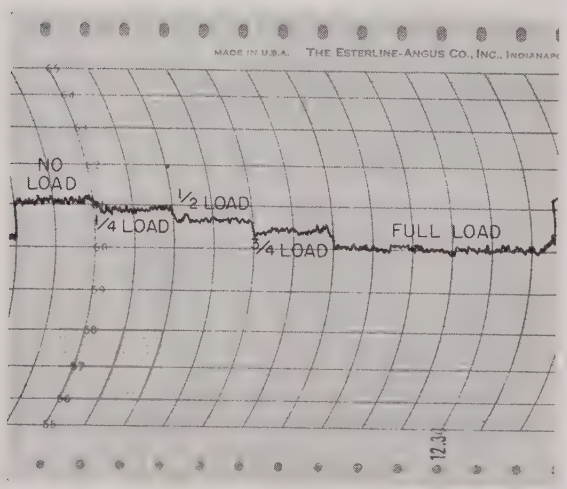


FIG. 1—*This record chart (No. 1515-E) shows the performance of an engine governor as load is removed from the generator. Specifications call for a minimum frequency variation and this chart shows a variation well within the requirements. (Courtesy Converto Mfg. Co., Cambridge City, Ind.)*

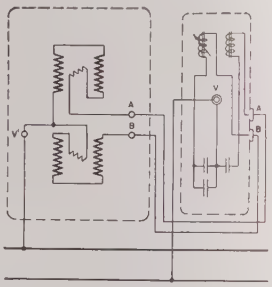
Model AW Frequency Recorders

Measuring Element No. 361.

Crossed-coil Electrodynamometer without springs, operating from resonant circuits.

Frequency Range (Cycles per Second)	Voltage Rating*
55-65	120
45-55	120
46-66	120
20-30	120

*120 volt recorder may be operated on 100-135 volts. For higher voltage ratings, see Multipliers, below.



Charts—Approximately uniform, expanded in middle portion. 1500 series, see chart list 355 or catalog section 90.

Scales—To match 1500 series charts.

Zero—Meter has no torque springs and no free zero. Position of pen can be adjusted slightly by means of key on multiplier. Adjustment may be required when operated from voltage source with a distorted wave form.

Leads—Furnished only with portables (5 feet) and twin wall types (3 feet). Longer leads can be used.

Binding Posts—Can be furnished instead of leads with portables.

Multipliers—Portable 50 or 60 cycle recorder has multiplier on case back. Other 50 or 60 cycle meters have one separate multiplier. Recorders for 25 cycles have 3 separate multipliers. All are deep style. Separate standard size multiplier is used with 120 volt instrument for 240, 480 and 240/480 volts.

Damping—Adjustable magnet and damper vane.

Response Speed—Time required for pen to complete swing one way varies with voltage, meter range, initial frequency, direction and magnitude of frequency change. Modest frequency changes on 55-65 cycle recorder at rated voltage require approximately 1¼ seconds for swing one way.

Dielectric Test—2500 volts, 60 cycles, for one minute.

Guaranteed Accuracy—2% of chart width.

Burden—Approximately 10 VA, 1.0 PF at 120 volts.

Potential Transformers—PT's or multipliers (see above) required above 135 volts. PT's can be control type; accurate ratio is not important.

THE ESTERLINE-ANGUS CO., INC.

Pioneers in the Manufacture of Graphic Instruments

P. O. BOX 596, INDIANAPOLIS 6, INDIANA

Catalog Section 38
Printed in U. S. A. 10M

Product Representatives in Most Principal Cities

ESTERLINE-ANGUS

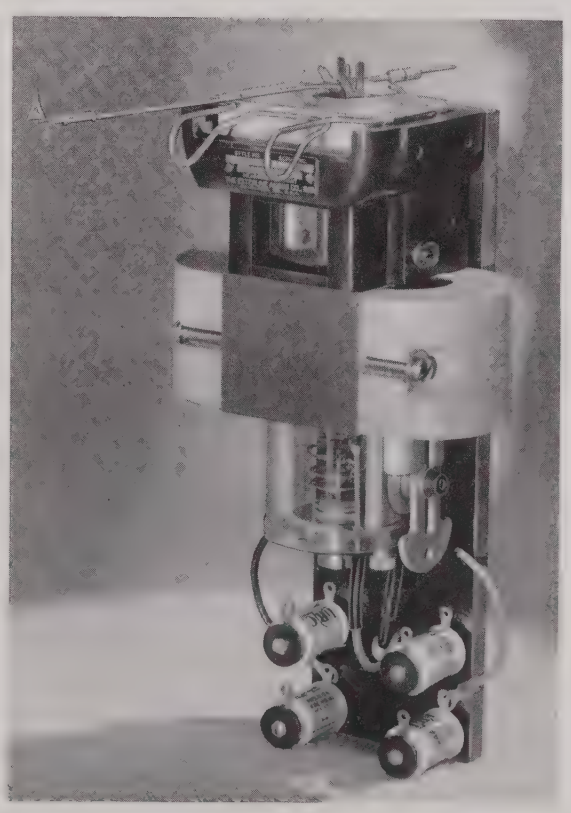
Recording

Direct Current Ammeters

Direct Current Voltmeters

Direct Current Millivolt-Voltmeters

PERMANENT-MAGNET, MOVING-COIL TYPE



Since its introduction, over one hundred years ago, men have been using and improving the permanent-magnet, moving-coil measuring element. New magnet materials, insulated wire with a better space factor, and modern manufacturing techniques have improved older designs and made the present-day sensitivities and performance the peak of the instrument maker's art.

Catalog Section 40
(August, 1958)

Direct Current Ammeters, Voltmeters and Millivolt-Voltmeters

using

Permanent-magnet, Moving-coil Measuring Elements

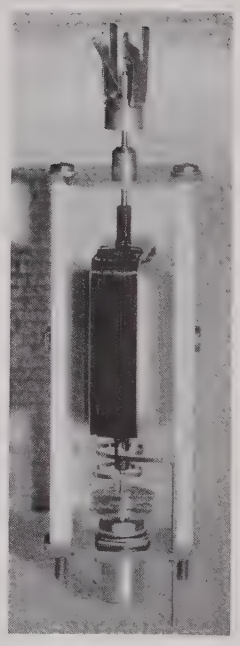


FIG. 2—*The moving element or armature of the permanent-magnet, moving-coil measuring element with soft iron core and supporting structure*

THE permanent-magnet, moving-coil measuring element uses two Alnico V permanent magnets to provide an intense magnetic field. The moving or measuring coil, with its soft iron core, Fig. 2, is immersed in this field. The pole pieces of the magnets and the soft iron core produce the radial, evenly distributed field required for linear response of the measuring element. As current flows, the measuring coil tries to turn so that the field established by the coil lines up with the field produced by the magnets. This movement is restrained by two springs, wound in opposite directions to eliminate possible spring errors.

After assembly in the magnet structure, the measuring unit is magnetized and covered by a transparent plastic cylinder or cup, Fig. 4, to keep iron particles and other extraneous matter out of the air gap. It is then ready for calibration and installation in a case, as illustrated in Fig. 4. A low resistance is connected in series with the moving coil to effect calibration of a DC ammeter and much higher resistance, with taps for various ranges, in a DC voltmeter. A magnetic shunt is also provided to assist in calibration and has an adjustment of approximately $\pm 3\%$. The top of the measuring element forms the receptacle for the inkwell, Fig. 3, and has two drain tubes to carry away any spilled ink. A canopy immediately below the pen fork protects the top bearing against ink spillage and prevents any material from traveling down the staff to current-carrying parts. Since the staff of the moving coil carries the pen, no linkages or servos, balancing circuits or relays are required. The measuring element develops sufficient torque to draw the record accurately on the moving chart.

All electrical connections are made to the terminal blocks, and the complete measuring element can be installed in or removed from the case as a unit. This measuring element is interchangeable with others, such as pressure, operation recorders and the dynamometer elements used in AC ammeters, voltmeters and wattmeters.

Damping

Damping of permanent-magnet, moving-coil measuring elements is accomplished by eddy currents flowing in (1) the frame on which the moving coil is wound and (2) in the circuit formed by the moving coil, leads and the measured circuit external to the meter. In the case of DC Ammeters, the millivolt drop of the shunt used has a marked effect on the speed of response of the meter. (See Fig. 7)

DC Ammeters

The DC ammeter is a very low-range voltmeter—a millivoltmeter—with a scale and chart having range numbers in amperes. It is operated from a shunt that produces a voltage, usually 100 millivolts, with rated current flowing in the line. Hence, the ammeter operates as a voltmeter and records the voltage, 0-100 MV, across the shunt terminals. E-A DC ammeters require 150 MA for full scale deflection, from left-hand zero.

Most indicating meter shunts are 50 MV and recording DC ammeters having a 0-50 MV range are regularly available. However, it is not good practice to make recording ammeters with a range lower than 0-50 MV, as they would have undesirable errors with changes in ambient temperature.

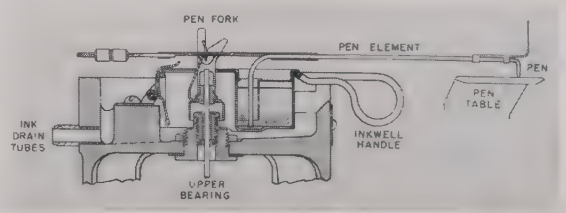


FIG. 3—*Cross sectioned view shows the top of the measuring element, with inkwell and pen element in place, drain tubes that prevent spilled ink from reaching any current-carrying parts, as well as the canopy protecting the upper bearing*

Leads

E-A has selected 0-100 MV as its standard, where no use on 50 MV shunts is indicated, for another reason. The DC ammeter reads a millivolt drop at the shunt end of its leads, which are part of the calibrated circuit. Five foot leads are furnished as standard. In most cases these standard 5-foot leads are long enough but there are applications, notably in steel mills, where it is physically impossible to mount a DC ammeter within 5 feet of its shunt. Leads 100 feet or more in length may be required. In such installations a 0-100 MV meter provides more margin for long leads without creating an undesirable temperature coefficient.

DC ammeters must be used with the leads furnished with them and these leads must not be changed or others substituted, unless they are made with the correct resistance or the meter is recalibrated. In the schematic diagram, page 7, the measuring coil, two leads and the calibrating resistor have a resistance of 0.6667 ohm for a 0-100 millivolt meter, or 6⅔ ohms per volt. Any change in this value produces an error in the record. For example, it is not unknown for a user to find that the distance from the shunt to the spot where he'd like to set his portable ammeter is 30 feet and the leads won't reach. So he cuts some No. 14 wire, twists it around the spade terminals on the shunt end of the leads and adds 25 feet to each lead. This total of 50 feet of No. 14 wire adds 0.131 ohm to the circuit and the total resistance is now 0.798 instead of 0.6667 ohm. This difference in lead resistance makes the ammeter read about 16.5% low.

Shunt Lead Compensator

When the exact lead length will not be known until the wire has been pulled into conduit, DC ammeters can be supplied with a shunt lead compensator. The meter is calibrated approximately 0-18 MV at the meter terminals and a series resistance spool of zero temperature coefficient wire is supplied for mounting on one of the terminal boards of the meter. After the meter is installed, wire is unwound from this spool until allowance has been made for the odd length leads. The wire is then cut off and soldered. The final overall calibration must be no lower than 0-50 MV. Lower values of calibration introduce significant temperature errors.

Use with Miscellaneous Shunts

At full scale, 150 MA flows through the meter and the shunt carries line current minus 150 MA. The current drawn by the meter is taken into account in making shunts up to and including 100 amperes. For example, a 5-ampere ammeter shunt produces 100 MV across its terminals with 4.85 amperes flowing through the shunt; 0.15 ampere through the meter then makes a total line current of 5 amperes. It frequently happens that a measurement is to be made and the correct *ammeter* shunt is not available. Let us say that a 100 ampere shunt is required and the only

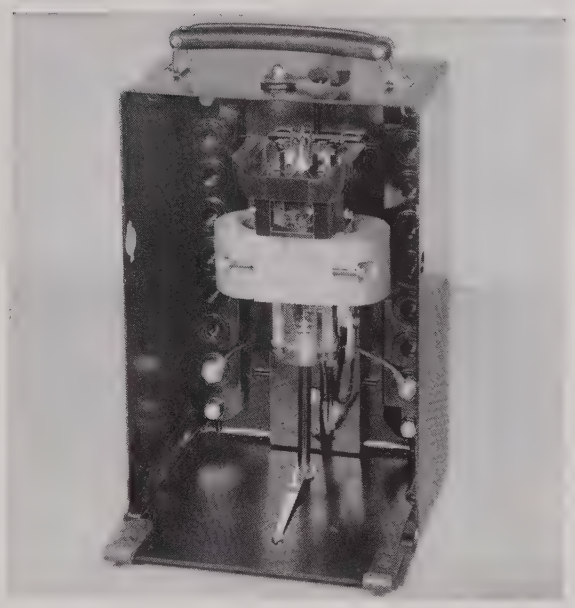


FIG. 4—*The permanent-magnet, moving-coil measuring element with its terminal blocks is installed in the case as a unit. It is interchangeable with other measuring elements, such as AC Ammeters and voltmeters. The transparent cup protecting the moving element is visible below the magnet structure*

shunt available is a 100 ampere, 100 MV, two-wire, *wattmeter* shunt. It is a simple matter to use this shunt, bearing in mind how it functions. A wattmeter shunt is normally calibrated for a meter current of 10 amperes. The 100 ampere wattmeter shunt will bring the DC ammeter to full scale with only 90.015 amperes in the line. Hence, this shunt must be considered to be a 90 ampere shunt when used with a recording ammeter.

Another possible circumstance is illustrated when it is desired to use a 50 MV indicating meter shunt with a graphic ammeter. An indicating meter will probably draw 1 or 2 or even 5 MA from its shunt at full scale and in making, say a 5 ampere shunt, the manufacturer would neglect the meter current. If we want to use such a shunt with a 0-50 MV graphic ammeter, the shunt will produce 50 MV with 5 amperes through it and 0.15 ampere through the meter. The line current will then be 5.15 amperes. If it is assumed that full scale is 5 amperes, readings will be interpreted 3% lower than they actually are.

A somewhat different situation exists if we want to use this 5 ampere, 50 MV indicating meter shunt with a 0-100 MV graphic ammeter. At full scale on the recorder, the shunt will be carrying 10 amperes and line current will be 10.15 amperes. The error due to neglecting meter current can be ignored; the important thing to note here is that at full scale the shunt is overloaded 100%. Most shunts do not have that much continuous overload capacity. This installation should be made only if it is known that the line current will not exceed 5 amperes.

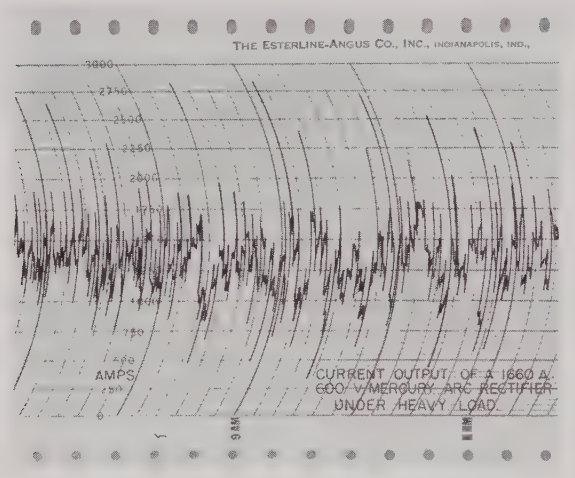

THE ESTERLINE-ANGUS CO., INC., INDIANAPOLIS, IND.,
AMPS.
CURRENT OUTPUT OF A 1660 A. 600 V. MERCURY ARC RECTIFIER UNDER HEAVY LOAD.
9 AM
11 AM

FIG. 5—*Graphic ammeter chart showing the current output of a 1000 KW, 600 volt mercury-arc rectifier under heavy load*

Measuring Large Currents

Since a shunt has a measurable voltage drop across its meter terminals, power is dissipated in it and heat is developed. The design of the shunt takes this into account and the manufacturer's instructions as to installation must be followed exactly to prevent overheating and consequent damage to the shunt. As the current to be measured becomes large, the shunt must be increased in size in order to provide proper heat dissipation. For example, a 1000 ampere shunt weighs 7 pounds but a 10,000 ampere shunt weighs 118 pounds.

These extremely high-current shunts are not only large and heavy, but the cost of building them goes up more rapidly than direct proportion to weight. Consequently when it is desired to measure heavy currents some means other than the use of large shunts should be considered. One method is to use two smaller shunts in parallel. For example, two 6000 ampere shunts are less expensive than one 12,000 ampere shunt. However, proper installation may prove to be quite difficult, so this method is not highly recommended.

A second method makes use of transductors rather than shunts. In general, transductors are much less expensive than large shunts. Their installation is similar to that of a through-type current transformer on an AC circuit; the transductor is merely slipped over the DC bus. A source of AC is required for excitation, but the power requirements are very small, and normal voltage fluctuations do not cause errors. A rectifier type recorder with special calibration is used. Transductors can be used for totalizing currents in two or more DC circuits. Additional information on the use of transductors on specific applications will be gladly furnished on receipt of details of the proposed installation.

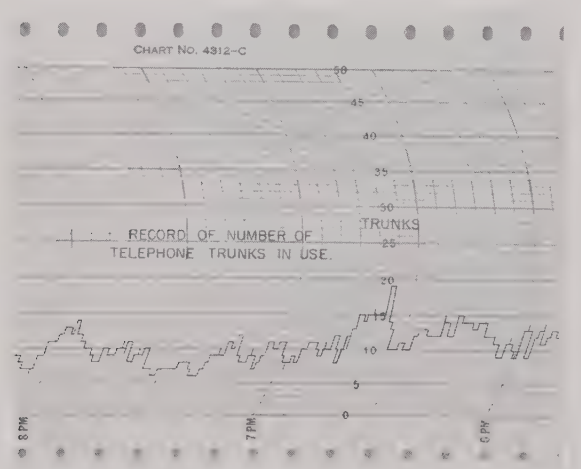


FIG. 6—*Records of the number of trunks in use between two telephone offices are valuable in studying the relation of capacity to volume of traffic and in planning future needs*

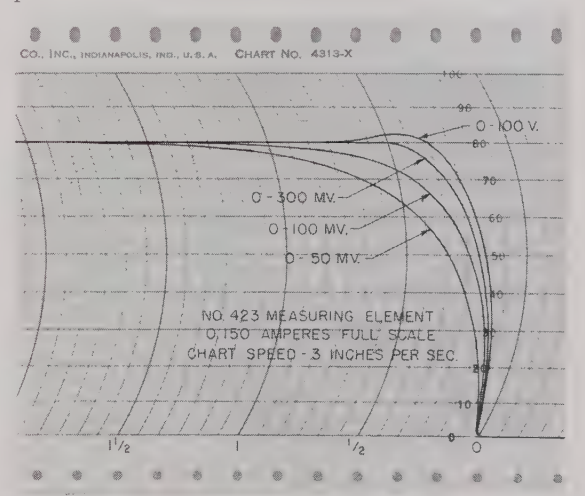

CO., INC., INDIANAPOLIS, IND., U.S.A. CHART NO. 4313-X
0 - 100 V.
0 - 300 MV.
0 - 100 MV.
0 - 50 MV.
NO. 423 MEASURING ELEMENT
0-150 AMPERES FULL SCALE
CHART SPEED - 3 INCHES PER SEC.

FIG. 7—*DC ammeters with 0-50 or 0-100 MV ranges are somewhat over-damped. Voltage ranges are more lightly damped as shown by the 100-volt curve*

Double Coil DC Ammeters

It is sometimes desired to totalize two currents or to record their difference. This can be done with a two-coil DC Ammeter, with coils connected to add or subtract. The two coils of such a meter are each equal to one-half the standard ammeter coil and can be connected in series or parallel. The voltage between coils must not exceed 135 volts.

Left-hand and Center Zero

Most DC ammeters are calibrated for left-hand zero. A zero shift lever in the bottom of the case makes it possible to set the pen point on zero. This lever also permits shifting the zero to the center of the scale. An instrument having a range of 0-100 MV, when shifted to center zero becomes 50-0-50 MV and the current to produce full scale deflection is 75-0-75 MA. It is permissible to shift a DC ammeter from left to center zero, and *vice versa*, at will. No overloading of the meter will occur. However, in

shifting a center zero meter to left-hand zero, the shunt may become overloaded. For example, assume that a 100-0-100 MV meter is shifted to left-hand zero. It then has a range of 0-200 MV. If the meter is connected to a 100 ampere, 100 MV shunt, the shunt will be fully loaded when the meter reads only one-half scale. This point must be borne in mind as shunts have no rated overload capacity.

Speed of Response

The time required for the pen to swing from zero to some instantaneously applied value is dependent on the range of the meter and the millivolt rating of the shunt. Fig. 7 shows response speeds of DC ammeters. Meters with 0-50 and 0-100 MV ranges have greater than critical damping. This is designed into the meters because they are often used on widely fluctuating loads where it is desirable to average out large instantaneous swings.

Scales and Charts

DC ammeters use evenly divided scales and charts. Scales to match any 4300 series chart (see catalog section 90) can be furnished. Permanently mounted ammeters used with a single shunt are usually equipped with a scale and chart to match the rating of the shunt. Portable meters, used with a variety of shunts or having several ranges, should be scaled for the lowest range or the most frequently used range on the meter.

DC Millivolt-Voltmeters

It is possible to add voltage ranges to a DC ammeter to make an ammeter-voltmeter or millivolt-voltmeter. The performance of these instruments as ammeters is exactly the same as described in the foregoing paragraphs. On the voltage ranges, they are more lightly damped as shown by the 0-100 volt curve in Fig. 7. Any combination of voltage ranges between 0-1 and 0-600 volts can be supplied.

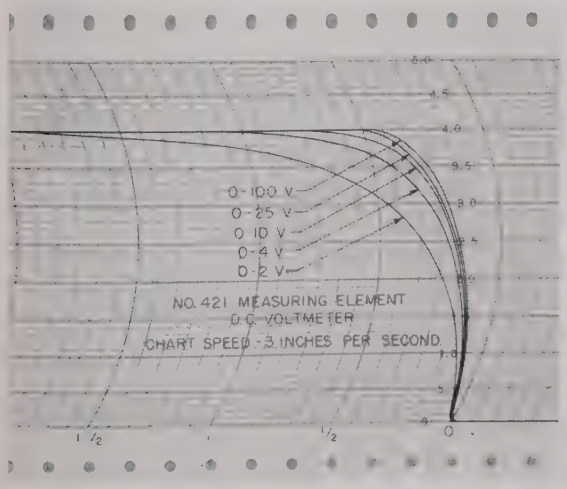


Fig. 8—*The 25-volt range represents critical damping. A very slight overshoot, practically unreadable, exists on the 100-volt range*

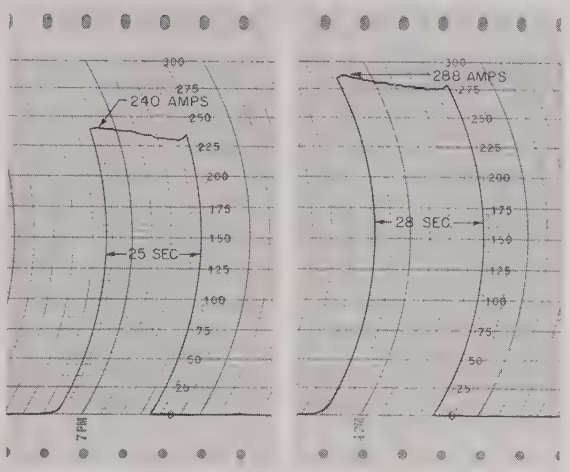


Fig. 9—*Recording ammeters simplify the job of checking and setting overload circuit breakers. Chart at the right shows performance of a breaker as received from the manufacturer, chart at left is the performance after proper adjustment*

The standard 5-foot leads are a part of the calibrated circuit of these meters also, and must be used on all ranges up to and including 0-1 volt. Since these meters draw 150 MA at full scale, ranges above 0-125 volts must have a multiplier box. This box is attached to the back of portable and flush meters and is mounted separately for front switchboard and wall meters.

Applications

DC ammeters and the millivolt ranges of DC Millivolt-Voltmeters are used in many ways:

- Motor currents—blooming mill, shearing motors, draft fans, printing presses, squeezers, elevators, paper machines, cranes, continuous steel mills, etc., to check operating condition and handling
- Train and car lighting—battery and generator performance
- Operation of controls and cutouts
- Adjusting circuit breakers and relays
- Plating and anodizing baths—correct current and length of cycle
- Arc welding—quality
- Electric hoists
- Electric trucks
- Power rectifier output
- Telephone equipment loading
- Current in cables, feeders and buses to find overloaded elements of a system
- Repetitious operations, such as grinding, polishing, machine tool time studies
- Dynamic braking
- Automobile and aircraft electrical systems

DC Voltmeters

The DC voltmeter reads voltage by measuring the current flow through an accurately adjusted resistance, connected in series with the armature of the

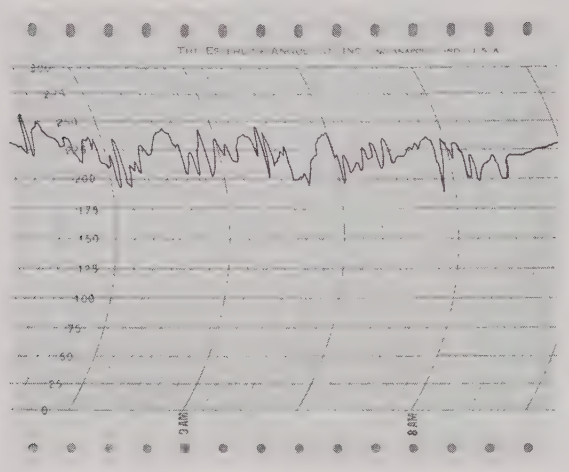


FIG. 10—*DC voltage chart on a feeder in a coal mine about one mile from the shaft. Variations in voltage are caused by cutting machines. Lowest points indicate several machines at peak load at the same time*

measuring element as shown in connection diagrams 2 and 3 on page 7. For ratings up to 800 volts this resistance is either inside the meter or in a multiplier box, attached to portable and flush meters and separately mounted for wall and front switchboard meters. The standard DC voltmeter uses measuring element No. 421 which has a sensitivity of 200 ohms per volt and takes exactly 5 MA full scale. Greater sensitivity can be furnished by using measuring element No. 424 (1.0 MA full scale) which produces a left-hand zero meter with a sensitivity of 1000 ohms per volt.

The lowest ranges available are 0-2 volts with 200 ohms per volt and 0-7.5 volts with 1000 ohms per volt sensitivity. These lower limits are established to make negligible the effect of the temperature coefficient of copper.

The upper limit of self-contained ranges is set at 800 volts principally for safety of operating personnel. Higher ranges can be supplied by means of a separate high-voltage multiplier box to be connected in series with a 750 or 800 volt range on the meter. Both the case of the meter and the separate high voltage multiplier must be grounded (special grounding terminals are provided) and the measured circuit must also be grounded as shown in diagram 3 on page 7.

Scales and Charts

Multi-range meters should have a scale and chart range equal to the lowest range on the meter or the range that will be most widely used. For example, a 0-150/300/600 volt instrument should have a 0-150 scale and chart. Single range meters can have a scale and chart to match any of the standard ranges in the 4300 series. (See catalog section 90).

Speed of Response

As shown in Fig. 8, lower ranges have a longer response time because the effect of the low resistance measuring circuit is quite pronounced. Critical damping resistance for the No. 421 measuring element used in DC voltmeters is about 5000 ohms. Since a 0-2 volt instrument, at 200 ohms per volt, has only 400 ohms total resistance, and the external circuit resistance is correspondingly low, the 2-volt recorder is over-damped. Voltage ranges above 0-100 have the same response as the 100 volt range because the external circuit produces no measurable damping and the coil frame does all of the work of limiting overshoot to negligible proportions.

Left-hand or Center Zero

Meters supplied as left-hand zero can be shifted to center zero; voltage to produce full scale deflection in either direction is cut in half. For example, a 0-600 volt instrument becomes 300-0-300 volts when shifted to center zero. The shift is made by moving the zero-shift lever on the bottom of the meter case. However, meters ordered as center zero, for example 300-0-300 volts, must not be shifted to left-hand zero, unless such use is specified when the meter is ordered. Where this use is specified the resistors will be so selected and arranged to dissipate the heat developed at 600 volts.

Applications

A few suggested uses of DC Voltmeters and the voltage ranges of DC Millivolt-Voltmeters are:

- Street railway and bus trolley voltages
- Ground detectors (See Fig. 12)
- Electric shovel operation
- DC plant feeder voltages
- Anodizing baths
- Train and automobile lighting studies
- Operating voltage of mills
- Battery voltage tests
- Operating troubles, excessive motor sparking, blown fuses, overheating

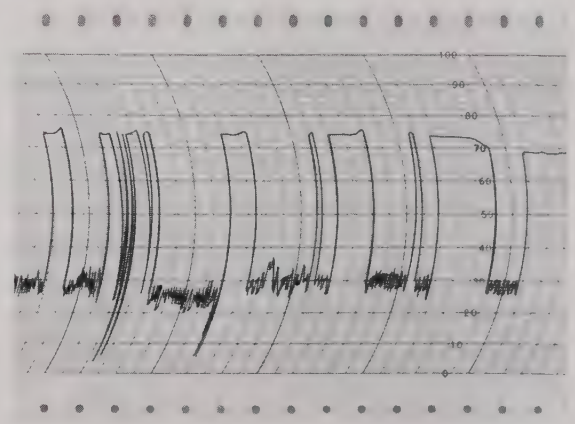


FIG. 11—*Chart of DC voltage across an electric arc during welding. After the first test, at right, welder output was changed and open circuit voltage rose to about 74. Low swings near left indicate repairing hole in seam by striking and withdrawing the arc a number of times*

Model AW DC Ammeters, Voltmeters and Millivolt-Voltmeters

	DC Ammeters Measuring Element No. 423	DC Millivolt-Voltmeters Measuring Element No. 423	DC Voltmeters Measuring Element No. 421
	Range in MV	**Range** **Millivolts** / **Volts**	**Range in Volts**
	0-50 0-100* 0-300 0-600 0-60 0-150 0-400 0-75 0-200 0-500 *Select 0-100 MV range if meter is to be direct-reading with standard 100 MV shunt.	0-50 0-200 / 0-1 0-50 0-60 0-300 / 0-2 0-100 0-75 0-400 / 0-5 0-150 0-100* 0-500 / 0-10 0-300 0-150 0-600 / 0-25 0-600	0-2 0-30 0-500 0-3 0-50 0-600 0-5 0-60 0-750 0-7.5 0-75 0-800 0-10 0-100 0-1000§ 0-15 0-150 0-1200§ 0-20 0-200 0-1500§ 0-25 0-300
Leads	5 foot calibrated leads with all types.	5 foot calibrated leads with all types. Must be used on all ranges up to 1 volt.	Furnished only with portable type, 5 ft. long. Leads not calibrated.
Binding Posts	Not permissible.	Permissible on ranges above 0-1 volt.	Can be supplied on portables instead of leads.
Multipliers	None required.	On ranges 125 V and above.	On ranges above 800 V.
Guaranteed Accuracy	1½% of full scale.	1½% of full scale.	1% of full scale.
Electrical Data	Left zero—150 MA full scale Center zero—75-0-75 MA	Left zero—6⅔ ohms per volt. Center zero—13⅓ ohms per volt.	Left zero—200 ohms per volt. Center zero—400 ohms per volt.
Special Ranges	Single range between 150 MA and 10 amp. self contained.	Any intermediate range.	Any intermediate range. 1000 ohms per volt can be furnished for ranges 0-7 to 0-800 volts. Milliampere ranges can also be furnished in addition to voltage ranges.
Shunts	Shunt rated other than 100 MV can be used with 100-MV meter, provided proper precautions are taken to prevent overloading shunt, if less than 100 MV. Shunt rating should usually be about 25% above full load current.		None

Shunt leads should not be switched unless all lead wire and switch are calibrated as a unit with the meter.
§When used on voltages above 800, one side of circuit must be grounded. Multiplier connections must be made to ungrounded line. Meter case and multiplier case must be grounded by means of the special terminals provided. (See Fig. 3, below).

Charts—4300 Series. Uniformly divided along pen arc. See catalog section 90.

Scales—To match any 4300 series chart.

Zero—Left-hand zero. Can be shifted to center zero. This cuts in half voltage and current for full scale deflection. Ammeter—Center zero meters can be shifted to left-hand zero but this may overload the shunt at full scale. Millivolt-Voltmeter and Voltmeter—Center zero meters must not be shifted to left-hand zero, unless such use is specified in ordering.

Multiranges—Nearly any combination of above or intermediate ranges.

Response Speed—Time required for pen to swing one way. Ammeter and Millivolt-Voltmeter—1 sec. for 100-MV range; 0.5 second for 300 MV range. Voltmeter—0.5 sec. ranges 0-15 V and above; 0-2 V range 1.25 sec.

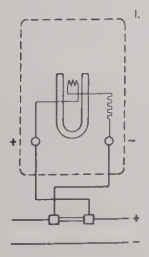
Insulation Test—5000 volts, 60 cycles, for one minute.

TABLE I—*Permissible Lead Lengths for Ammeters and Millivolt Ranges of Millivolt-Voltmeters**

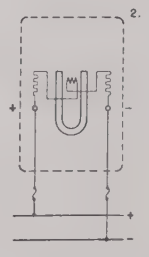
Range in MV	Maximum Allowable Resistance between Shunt and Meter (in ohms) for left-hand zero meter†	Corresponding Approximate Length in Feet (one way) of Average Copper wire leads at 30°C		
		No. 10	No. 8	No. 4
0-50	0.133	65	100	255
0-60	0.200	95	150	385
0-66⅔	0.244	115	185	470
0-75	0.300	145	230	580
0-100	0.467	225	355	900
0-125	0.633	305	485	1220
0-150	0.800	385	610	1540
0-200	1.133	545	860	2190

*Based on a full-scale current of 0.150 ampere and a drop of 30 MV at meter terminals. Where longer leads are necessary a special measuring element can be furnished.

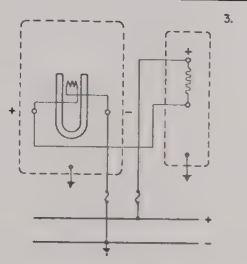
†For a center-zero meter, use lead data for left-hand zero meter having twice the full scale MV. Example: For a 100-0-100 MV meter, use lead data for 0-200 MV meter. In calculating resistance of leads, their average operating temperature must be allowed for. Standard calibration is on the basis of a lead temperature of 30° C. (86° F.)



Internal and external wiring diagram of a DC ammeter with shunt



DC voltmeter with range up to 0-800 volts



DC voltmeter with range over 0-800 volts. One side of circuit must be grounded

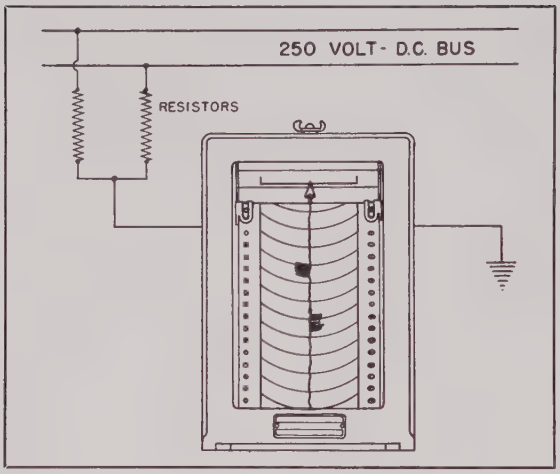


FIG. 12—*The connection diagram shows a center-zero recording voltmeter used as a ground recorder*

Cases

Portable, wall, flush and front switchboard single case styles are available. The permanently mounted styles, wall, flush and front switchboard, can also be furnished in twin mounting. The case bodies are die-cast aluminum alloy, finished with black baked enamel. Flush single and twin cases are equipped with fluorescent lighting for 120 volts, 60 cycles. For certain other voltage sources, incandescent lighting is supplied.

Chart Drives

A large variety of chart drives and chart speeds provides the user with the utmost flexibility he requires to meet conditions in his particular plant. Briefly, they are divided into three general classes:

Hand-wound spring
Motor-wound spring
Synchronous motor

Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. The change from inches per hour to inches per minute can be made manually by means of a shift lever, or electrically, with the addition of a shift coil inside the chart drive.

Higher chart speeds are sometimes required to study short time intervals, and external motors, providing speeds of ¾, 1½ and 3 inches per second, can be supplied. For high speed fault recording, this external drive, called Type R, resets the chart to correct time of day after each high speed run.

When instruments are combined in twin cases, both charts can be driven by a single chart drive, mounted in the right-hand half of the twin. The other half of the twin then uses a slave mechanism, called a phantom chart drive. Phantom drives can also be used where it is desired to drive the chart from an external source.

How to Order—*Specify:*

1—Case Style: Portable, Flush Switchboard, Front Switchboard, Wall mounting.

2—Chart Drive: Hand-wound spring, Motor-wound spring, Synchronous. If electric, give voltage and frequency. If electric hour-to-minute feed shift desired, give voltage and frequency.

3—Measuring Element: Amperes, millivolts or volts of ranges desired. Left-hand or center zero.

4—Leads: Length of leads, if standard 5-foot leads cannot be used. Shunt lead compensator.

5—Shunts: Are we to furnish? Millivolt drop. Ampere rating. Portable or switchboard. (Ammeter shunts with 50 or 100 millivolts drop are available in ratings of ¼-10,000 amperes in switchboard mounting; ¼-5000 amperes, portable.

6—Scale and Chart: Range numbers desired on chart and scale. Chart speed.

7—Extra Features: Writing-door, glass corner in case cover, right and left-hand chronograph pens (give voltage and frequency).

8—Accessories and Supplies: such as, chart inspector, extra pen elements, pen points, pen point cleaners, charts, ink, carrying case.

THE ESTERLINE-ANGUS COMPANY, INC.
Pioneers in the Manufacture of Graphic Instruments
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

ESTERLINE ANGUS

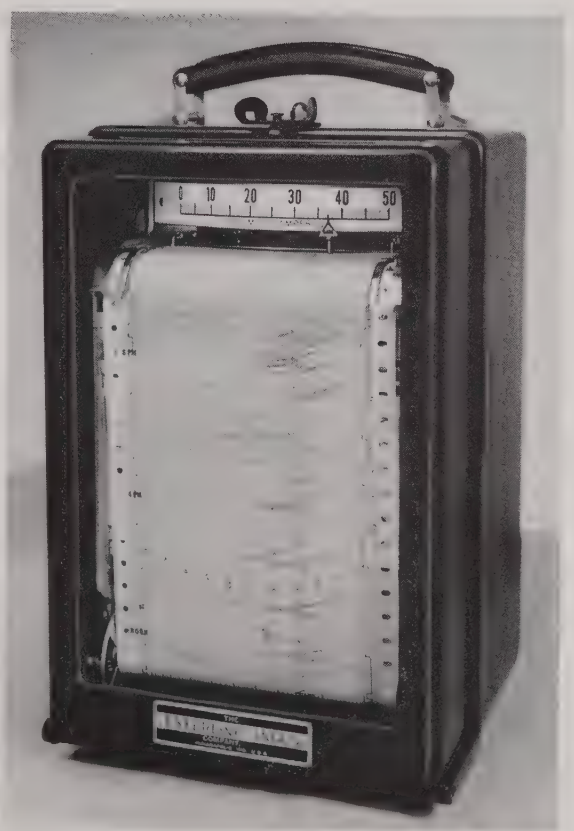
RECORDING DIRECT CURRENT MICROAMMETER

(Basic range 0-50 microamperes DC)

The versatile DC Microammeter by Esterline Angus is a favorite for scores of uses in industry, nuclear research and development, and medical electronics. Low input requirements permit its direct use, in almost all cases, without modification of the circuit to be measured.

Two exclusive features account for the instrument's versatility. It operates on 120-volt alternating current in a frequency range from 50 to 400 cycles. (This means it can be used overseas, where 50 cycle frequency is common, or in aircraft which usually have 400 cycle generators.) It can be ordered to operate on power supplied by a 12-volt battery, making it independent of any other power source.

Most important, this DC Microammeter provides the excellence of design and ruggedness of construction which have characterized Esterline Angus instruments for more than 50 years.



High sensitivity, stability, linearity, long-time reliability, and freedom from drift are qualities which have earned for the Esterline Angus DC Microammeter a reputation as the acknowledged leader in the instrument industry.

Because of its high sensitivity, the instrument can be used in most circuits without auxiliary equipment. In industry, applications include use of the instrument with electronic gages which have only an indicating meter. Permanent records furnished by the instrument help gage production runs to assure quality control.

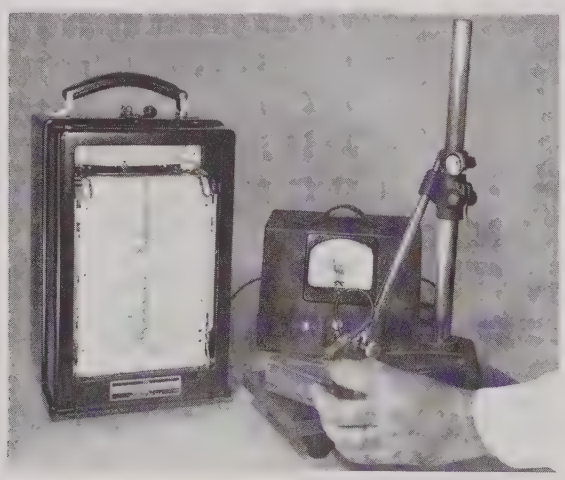


Fig. 1—The DC Microammeter shown above has been installed in series with the indicator of an electronic gage to plot the irregularities in the surface of a metal strip. Each minor division of the chart indicates ten one-millionths of an inch deviation. (Gage courtesy of Merz Engineering, Inc., Indianapolis, Indiana.)

In automated or semi-automated plants, the instrument is a reliable trouble-shooting aid for checking electronic systems. It can be substituted for, or placed in series with, any indicator which has a range as low as 0-50 microamperes DC.

Research and development uses vary with the project. The instrument can, however, be employed in various ways to complement numerous research techniques and projects.

For example, it can be used with photo-electric cells, vibration pick-ups, strain gages, thermo-couples and other primary detecting devices. Other possible applications include its use with gas analyzers, phototronic devices and audiometers.

When used with proper detectors, the instrument will produce recordings which show the distribution of tracer elements in nuclear studies. In addition, it can be used with scintillators and air samplers to gather permanent data on radioactive material present in a particular environment.

In medical electronics, the instrument can be employed with diagnostic equipment to provide permanent records of the oxygen content of the blood, the results of respiratory gas analysis, psychogalvanic reactions and medical spectrometry.

Fig. 2—The moving element or armature of the permanent-magnet, moving-coil measuring element with soft iron core and supporting structure.

The Esterline Angus DC Microammeter has been made possible by combining our permanent-magnet, moving-coil measuring element with an especially-designed magnetic amplifier.

The measuring element uses two Alnico V permanent magnets to provide an intense magnetic field. The moving or measuring coil, with its soft iron core (Figure 2), is immersed in this field. The pole pieces of the magnets and the soft iron core produce the radial, evenly distributed field required for linear response of the measuring element. When current flows in the measuring coil, a torque is produced. This torque is resisted by two springs wound in opposite directions to minimize spring errors. The resulting deflection is proportional to the current flowing in the coil.

The magnets are energized after they are assembled in the measuring element. A transparent plastic cylinder around the coil prevents iron particles and other extraneous matter from entering the magnetic air gap. A magnetic shunt is provided for changing calibration and has an adjustment of approximately ± 3%. The top of the measuring element forms the receptacle for the inkwell (Figure 3) and has two drain tubes to carry away any spilled writing fluid. A canopy immediately below the pen fork protects the top bearing against writing fluid spillage and prevents any writing fluid from traveling down the staff to current-carrying parts. Since the staff of the moving coil carries the pen, no linkages or servos, no balancing circuits or relays are required.

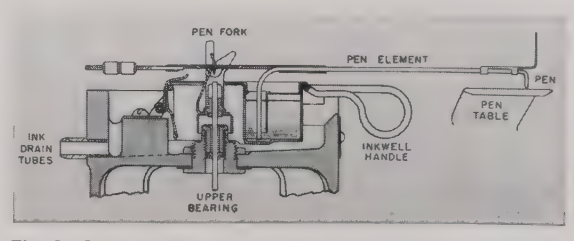


Fig. 3—Cross-sectioned view shows the top of the measuring element, with inkwell and pen element in place, drain tubes that prevent spilled writing fluid from reaching any current-carrying parts, as well as the canopy protecting the upper bearing.

The magnetic amplifier, encapsulated for protection against environmental damage, along with the power supply is mounted inside the recorder case.

The amplifier is guaranteed to have stability and long life. Tantalum capacitors, silicon rectifiers, and stabilized magnetic materials are used in its construction. Combining this amplifier with the rugged movement produces a reliable recorder fully comparable in quality with other use-proven Esterline Angus instruments. The instrument is purposely simple in design to eliminate time-consuming adjustments. It can be placed in service merely by connecting the signal input and power supply leads.

All electrical connections are made to the terminal blocks, and the complete measuring element with magnetic amplifier can be installed in or removed from the case as a unit.

Response

When the instrument is used in circuits which have a resistance of 5000 ohms or more, the response time for the pen to travel from zero to 99% of its final indicated value will not exceed one-half second after application of signal. When the instrument is used in circuits having a resistance lower than 5000 ohms, response is slower than one-half second. See family of curves (Figure 4) which illustrates response.

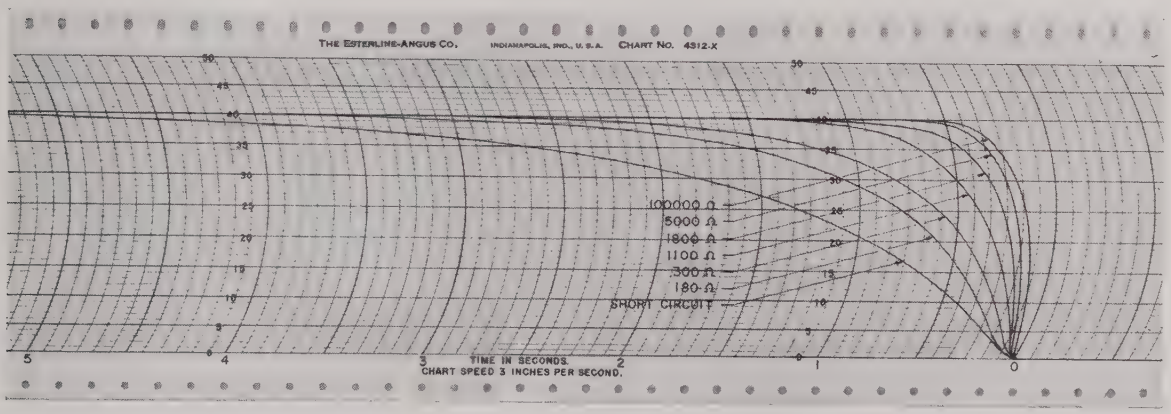


Fig. 4—This family of curves illustrates the response time of the DC Microammeter when used in circuits of various resistances. In making each curve, the current was changed instantaneously from 0 to 40 microamperes.

Scales and Charts

The DC Microammeter uses evenly divided scales and charts. Scales to match any 4300 series chart (see Catalog Section 90) can be supplied. It usually will be most convenient to use a chart with a range of 0-50 together with an appropriate multiplying factor.

Left-Hand or Center Zero

The instrument may be used with a normal left-hand zero or it may be set for center zero operation. The latter permits use in such applications as null detection in bridge circuits. (Right-hand zero operation available on special order.)

Setting the instrument to zero can be accomplished by adjusting the zero shift lever located over the nameplate on the bottom of the instrument case. This setting should be made after the instrument has been connected to the power source and has warmed up for 30 minutes, and while no signal is applied to the recording terminals. Setting the zero without warm-up can result in an overall instrument error of 3% of full scale.

With left- or right-hand zero, the full scale range is 50 microamperes DC. With center zero, the instrument range becomes 25-0-25 microamperes DC.

Shifting the zero from left- or right-hand to center, or vice versa, will not upset the instrument's accuracy or linearity.

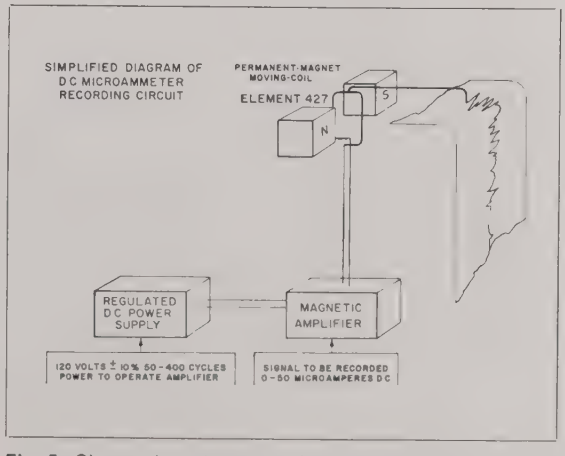

SIMPLIFIED DIAGRAM OF DC MICROAMMETER RECORDING CIRCUIT
PERMANENT-MAGNET MOVING-COIL ELEMENT 427
S
N
REGULATED DC POWER SUPPLY
MAGNETIC AMPLIFIER
120 VOLTS ± 10% 50-400 CYCLES POWER TO OPERATE AMPLIFIER
SIGNAL TO BE RECORDED 0-50 MICROAMPERES DC

Fig. 5—Shown above is a simplified block diagram of the circuit used in the DC Microammeter. On special order, the instrument can be arranged so that the amplifier can be powered by a 12 volt ± 5% DC supply.

Type 601 Direct Current Microammeter
427 Permanent Magnet Moving Coil Measuring Element in Combination with Magnetic Amplifier No. 14410
(Range 0-50 microamperes DC. Input resistance approximately 200 ohms.)

Charts—Uniformly divided, 4300 series, refer to Catalog Section 90.

Scales—To match any 4300 series chart. Suggested scale 0-50.

Zero—Left-hand or center zero. Shifting to center zero cuts in half the full scale current. (Right-hand zero available on special order.)

Leads—None furnished. Lead resistance not critical.

Binding Posts—Regularly furnished on portables.

Response—One-half second for most circuits. See Figure 4.

Warm-Up—For best results, the instrument should be allowed to warm-up for 30 minutes before recordings are taken. This 30-minute warm-up period is recommended to assure maximum accuracy and stability.

Overload Capacity—100 times range for period of one second. 20 times range continuously.

Accuracy—2% of full scale after 30-minute warm-up. Error without warm-up not to exceed 3% of full scale.

Dielectric Test—500 volts DC for one minute between all terminals tied together and the case.

Power Requirements—Exclusive of chart drive, 15 VA at 120 volts ± 10%, 50 to 400 cycles. (On special order, 4 watts at 12 volts ± 5% DC.)

Temperature Effect—The instrument will not be affected by changes in temperature within 20-120 degrees F.

Special Ranges—Current ranges greater than 50 microamperes can be furnished. The instrument can also be supplied as a voltmeter with a 20,000 ohm/volt sensitivity. Write to us describing your requirements. We'll do our best to meet them.

Cases

Portable, wall, flush and front switchboard single cases are available and all but portable are also furnished in twin mounting. Flush cases have 120 volt, 60 cycle fluorescent lighting. If preferred, incandescent lighting can be supplied.

Chart Drives

Synchronous motor or hand-wound spring drives will generally apply. Other types such as phantom and motor-wound spring drives are available. The motor or spring drives provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. The change from inches per hour to inches per minute can be made manually by means of a shift lever or electrically with the addition of a shift coil inside the chart drive.

HOW TO ORDER—Specify

1—Case style (Catalog Section 15): Portable, flush switchboard, front switchboard, wall mounting.

2—Chart drive (Catalog Section 20): Synchronous motor, hand-wound spring or other. If electric, give voltage and frequency. If electric hour-to-minute shift desired, give voltage and frequency.

3—Scale and chart (Catalog Section 90): Range numbers desired on chart and scale. Chart speed.

4—Rating of amplifier power supply: 120 volts, 50 to 400 cycles; or 12 volts DC.

5—Accessories and attachments (Catalog Section 80): Writing door, glass corner in case cover, chart inspector, carrying case, right- and left-hand chronograph pens (give voltage and frequency).

6—Supplies (Catalog Section 90): Charts, extra pen elements, pen points, pen point cleaners, writing fluid.

Fig. 6—A highly useful "extra" is the chronograph pen encircled at right. One pen can be mounted to record in each margin of the chart. These devices are useful for keying some other event to the main record. They are operated by a rugged electromagnet which can be rated for AC or DC voltages.

ESTERLINE ANGUS INSTRUMENT COMPANY, INC.
Excellence in graphic recording for over 50 years
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

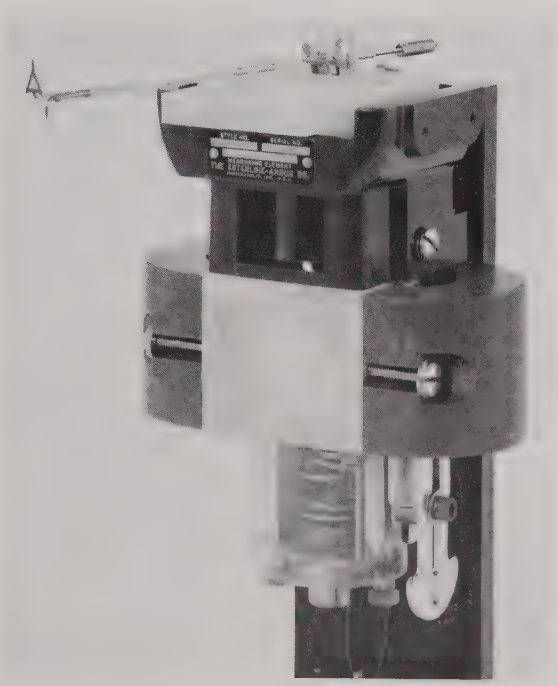
ESTERLINE-ANGUS

Recording

PERMANENT-MAGNET, MOVING-COIL TYPE

Direct Current Milliammeters

Since their introduction over 20 years ago, Esterline-Angus DC Milliammeters have proved to be stalwart members of the E-A family of recorders. They have distinguished themselves in the armed forces, have assisted in nearly every type of research from the development of atomic energy to the perfecting of new medical techniques, and have proved to industry that sensitivity and ruggedness can be combined in one instrument. Today's E-A milliammeters embody the latest in component design and instrument making technique. They are truly leaders in their field.



Catalog Section 42

(February 1960)

PERMANENT-MAGNET, MOVING-COIL

Direct Current Milliammeters

BASIC SENSITIVITIES: 0-1, 0-5, 0-50, 0-150 DC MA

FIG. 1—*The moving element or armature of the permanent-magnet, moving-coil measuring element with soft iron core and supporting structure*

THE permanent-magnet, moving-coil measuring element uses two Alnico V permanent magnets to provide an intense magnetic field. The moving or measuring coil, with its soft iron core, Fig. 1, is immersed in this field. The pole pieces of the magnets and the soft iron core produce the radial, evenly distributed field required for linear response of the measuring element. When current flows in the measuring coil, a torque is produced. This torque is resisted by two springs wound in opposite directions to minimize spring errors. The resulting deflection is proportional to the current flowing in the coil.

After assembly in the magnet structure, the magnet is magnetized and the moving coil is covered by a transparent plastic cylinder Fig. 4, to keep iron particles and other extraneous matter out of the air gap. It is then ready for calibration and installation in a case, as illustrated in Fig. 4. A magnetic shunt is provided for changing calibration and has an adjustment range of approximately $\pm 3\%$. The top of the measuring element forms the receptacle for the inkwell, Fig. 2, and has two drain tubes to carry away any spilled ink. A canopy immediately below the pen fork protects the top bearing against ink spillage and prevents any ink from traveling down the staff to current-carrying parts. Since the staff of the moving coil carries the pen, no linkages or servos, balancing circuits or relays are required.

All electrical connections are made to the terminal blocks, and the complete measuring element can be installed in or removed from the case as a unit. This element is interchangeable with all other E-A measuring elements.

Damping and Swinging Speed

The user of an indicating instrument is usually not concerned with the dynamic properties of his instrument, but in a recorder these properties are very important. If the pen moves so slowly that it fails to follow rapid changes, or if it overshoots on sudden swings and thus records values which did not exist, the usefulness of the instrument is seriously impaired. For most purposes, therefore, the measuring element of a recorder should have a high swinging speed, and at the same time it should be well damped so it does not overshoot. In most other Esterline-Angus recorders, swinging speed and damping are determined entirely by the design of the instrument, and are unaffected by the characteristics of the circuit in which the instrument is operated. In these sensitive DC milliammeters, however, swinging speed and damping vary with circuit resistance. This has the advantage that the response of the instrument may be adjusted by the user, but requires a knowledge of these properties so that the circuit resistance may be selected to give the desired performance.

The damping of the recording milliammeter is made up of two components, one of which is fixed, and the other of which varies with circuit resistance. The fixed component is produced by eddy currents which flow in the metallic frame of the moving coil. The variable component is caused by the generator action of the coil rotating in the magnetic field. This action results in a current which during rotation opposes the current being measured, thus retarding the motion of the coil. The value of this opposing current is partially determined by the resistance of the external circuit; the lower the resistance of the circuit, the larger the opposing current, and the heavier the

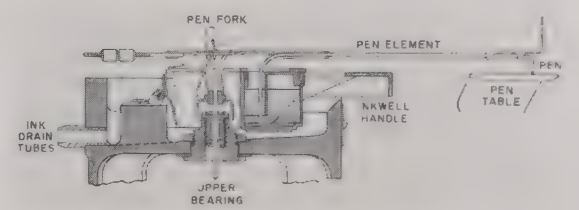


FIG. 2—*Cross-sectioned view shows the top of the measuring element, with inkwell and pen element in place, drain tubes that prevent spilled ink from reaching any current-carrying parts, as well as the canopy protecting the upper bearing*

damping effect. By proper selection of circuit resistance it is possible to vary the swinging time from about ½ second to about 5 seconds.

For most instrument applications, it is desirable for the pen to move from one equilibrium position to another in the shortest possible time, but with no overshoot. Such a condition is called "critical damping." These recording milliammeters have been carefully designed so that the fixed component of damping produces nearly critical damping. The slight additional damping produced by the high-resistance circuits in which the instruments are ordinarily used, then produces fully critical damping. If maximum swinging speed is wanted, to make the instrument most sensitive to short-time transients, the instrument should be operated in a circuit of the highest possible resistance. This reduces the variable component of damping, producing an instrument of maximum speed. On the other hand, if a slow swinging speed is wanted, to give an average record unaffected by short-period changes, the instrument should be operated in a low-resistance circuit. This increases the variable component of damping, producing a slow-swinging, overdamped instrument.

These characteristics are shown in Figs. 5 and 8. In Fig. 5 for the 0-1 MA recorder, curve B shows that critical damping is obtained with an external circuit resistance of about 50,000 ohms. Under these conditions there is no overshoot, and the instrument completes its swing in about ½ second. Circuit resistances higher than the critical value make only a small change in properties (See Curve A). Circuit resistances lower than the critical value cause the instrument to swing more slowly (See Curves C to H). In circuits of very low resistance about 5 seconds are required to complete the swing.

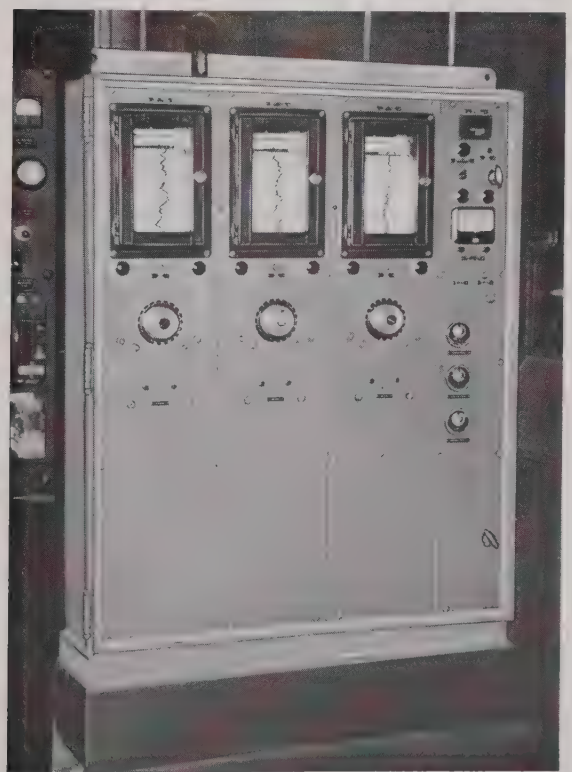


FIG. 3—*Three DC milliammeters on the panel of Caliper and Weight Control manufactured by Electric Eye Equipment Co., Danville, Illinois*

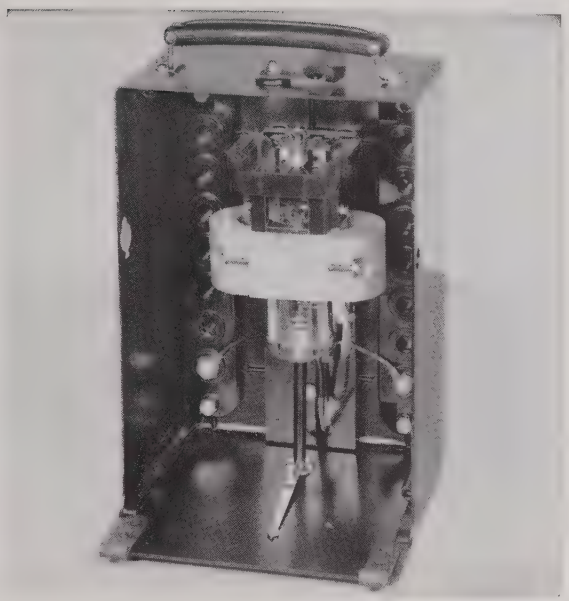


FIG. 4—*The permanent-magnet, moving-coil measuring element with its terminal blocks is installed in the case as a unit. It is interchangeable with other measuring elements, such as AC ammeters and voltmeters. The transparent shield around the moving element is visible below the magnet structure*

Fig. 8 shows comparable data for the 0-5 MA recorder. Curve B shows that critical damping is obtained with an external circuit resistance of about 4000 ohms, producing a swinging time of about ½ second. For other values of resistance, the performance of the 0-5 MA recorder follows the same pattern as the 0-1 MA instrument.

The curves in Figs. 5 and 8 show what the performance of the meter will be in an existing circuit of any particular resistance. They also show what circuit resistances should be used to obtain critical damping, or to obtain maximum response to short transients, or to cause the meter to average out short-time fluctuations.

Effect of AC Component

Since these milliammeters are DC instruments, they do not permanently deflect when AC is applied. However, due to the instrument's high swinging speed, AC may cause the recording pen to vibrate, particularly if the magnitude of the AC is great or if the frequency is low. No harm will occur provided the AC does not actually overload the instrument; however, a strong AC component may cause skipping

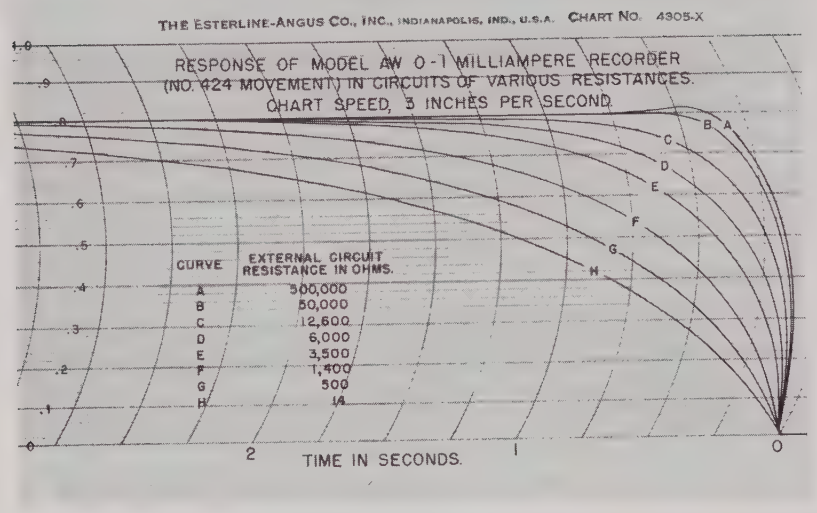


FIG. 5—*This family of curves illustrates the response speed and damping of the 0-1 MA recorder in circuits of various resistances. In making each curve, the current was changed instantly from 0 to 0.8 MA. Critical damping occurs when the external circuit resistance is about 50,000 ohms (Curve B); response time is then about ½ second. Shunted ranges are slower in response. A 0-2 MA range is represented by curves C and F, the first of these showing results with the standard arrangement employing both series and parallel resistance, and the other with a direct shunt across the armature coil. Curves D and H correspond to a 0-100 MA range, with the same two methods of shunting*

in the record due to this vibration of the pen. If the instrument is to be used on a DC circuit having a heavy AC component, it may be necessary to shunt a high-capacity condenser across the instrument terminals.

Temperature

Ordinary temperature changes do not affect the current calibration; the only effect of a moderate change in temperature is to alter the resistance of the coil, and hence the voltage drop across it.

Multi-range Milliammeters

Shunting the instrument to produce a higher current range is equivalent to operating it in a circuit of low resistance. If the shunt is connected directly across the armature, overdamping is the result. By first adding series resistance and then putting a shunt around the armature with its series resistance, considerably better swinging characteristics are obtained; the slowest range then has a response speed of approximately 1¼ seconds. This construction results in a higher resistance and a higher voltage drop on all shunted ranges, but this is usually of small consequence. The difference in characteristics between the standard series-parallel shunt arrangement and direct shunting, as applied to the 0-1 MA basic element, is well illustrated by Curves C and F in Fig. 5. Multi-range instruments using the basic 0-1 MA element have standard characteristics for the 0-1 MA range; higher current ranges all have a drop of 7.0 volts at full scale. Similarly, if the 0-5 MA basic element is used, the multi-range instruments have

FIG. 7—*Air Monitor incorporating a 0-1 MA, flush DC milliammeter for recording radioactivity of gaseous mixtures. (Courtesy Nuclear Measurements Corp., Indianapolis)*

Photo: The Inman Co., Long Beach

FIG. 6—*E. L. Decker, president, Martin-Decker Corp., Long Beach, Calif., and Karl L. Kellog, drilling contractor, observing a DC milliammeter recording performance of a drilling rig*

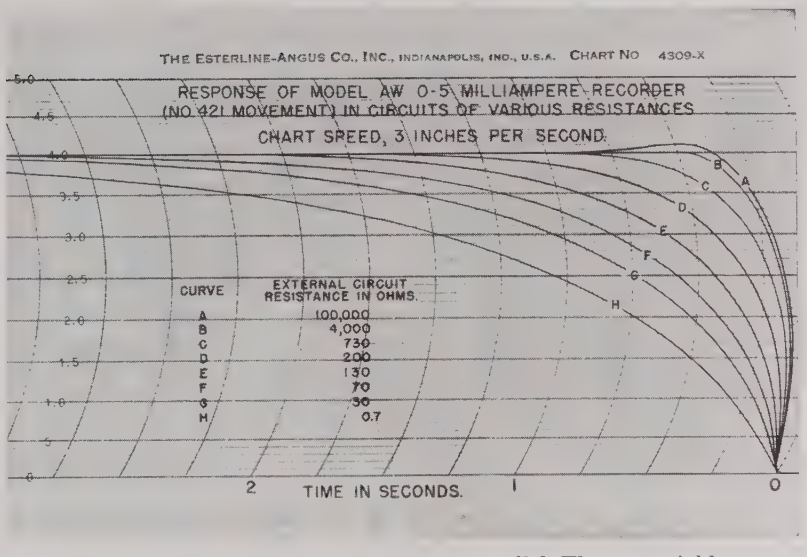


FIG. 8—*This family of curves illustrates the response speed and damping of the 0-5 MA recorder in circuits of various resistances. In making each curve, the current was changed instantly from 0 to 4.0 MA. Critical damping occurs when the external circuit resistance is about 4000 ohms (Curve B); response time is then about ½ second. Shunted ranges are slower in response. A 0-10 MA range is represented by curves C and F, the first of these showing results with the standard arrangement employing both series and parallel resistance, and the other with a direct shunt across the armature coil. Curves D and H correspond to a 0-500 MA range, with the same two methods of shunting*

standard characteristics for the 0-5 MA range but higher ranges have a 2.0 volt drop at full scale.

Multi-range milliammeters have only two terminals, the various ranges being obtained with a tap switch, usually mounted in the case. It is recommended that the highest range on a multi-range recorder be not greater than 100 times the lowest range. However, it is possible to provide ranges up to 1.0 ampere with the No. 424 measuring element and up to 2.0 amperes with the No. 421 measuring element, if the full scale voltage drops of 7.0 and 2.0 volts, respectively, can be tolerated. Elements Nos. 422 and 423 are not used in multi-range instruments.

Double Coil DC Milliammeters

Double coil milliammeters can be furnished to record the sum or difference of two currents. The two coils of such recorders each have one-half the number of windings of a corresponding single coil instrument. The two coils are electrically separate but can be connected in series or parallel. The potential between coils must not exceed 135 volts.

Left-hand or Center Zero

Most DC milliammeters are calibrated for left-hand zero. A zero shift lever in the bottom of the case is provided to set the pen point on zero. This lever also permits shifting the zero to the center of the scale. An instrument having a range of 0-1 MA becomes 0.5-0-0.5 MA when shifted to center zero and the voltage drop across it is changed from 0-1.4 volts to 0.7-0-0.7 volt. It is permissible to shift the zero of a DC milliammeter from the left to center and *vice versa* at will. No overloading of the measuring circuit will occur.

Overload Capacity

The factor of safety in the design of these permanent-magnet, moving-coil measuring elements is

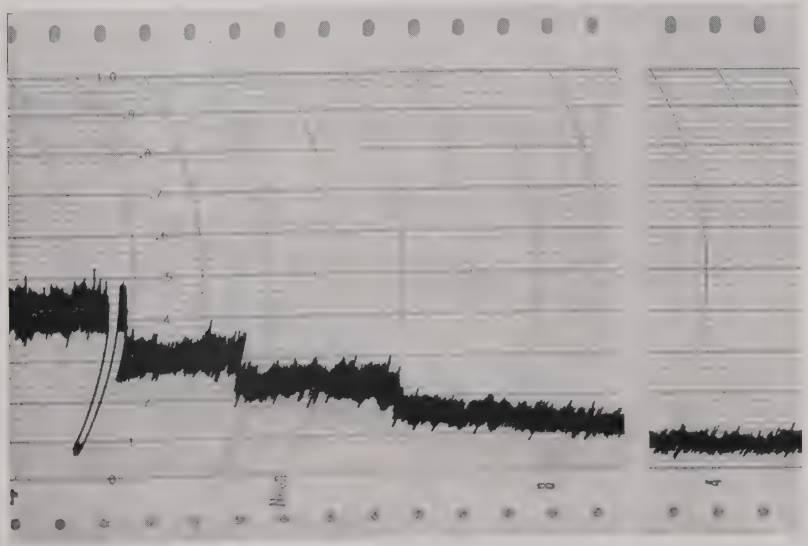


FIG. 9—*Radioactive fall-out record at Indianapolis made by the equipment in Fig. 7. At right, normal radioactivity is shown. The record had remained at this level for 1½ days after explosion of a test bomb before it gradually climbed to 0.12 on the chart. Then as the winds brought the radioactive products over the city, the fall-out increased as shown at the left. No question of safety was involved as the fall-out even at the highest points recorded was an insignificant portion of the safe value*

such that the basic 0-1 MA recorder will carry 25 MA continuously without overheating. Similarly, the 0-5 MA instrument will carry 100 MA.

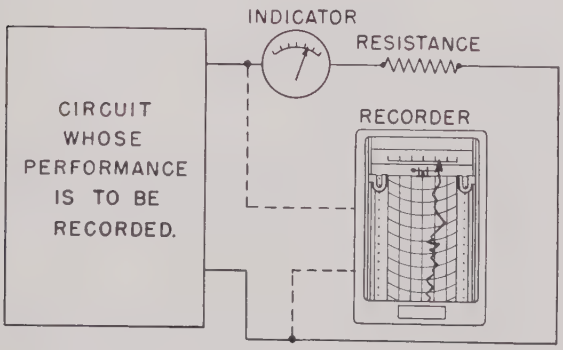
It is obvious from these figures that an overload will not of itself damage a DC milliammeter. The criterion is how the overload is applied. If the current value in excess of full scale builds up gradually, no damage can occur. If the over-current is applied suddenly, it is possible to throw the pen element out of the pen fork. Replacing the pen element in the pen fork is all that is necessary as no permanent damage is done by such an occurrence.

Scales and Charts

DC milliammeters use evenly divided scales and charts. Scales to match any 4300 series chart (See Catalog Section 90) can be supplied. On multi-range recorders the scale and chart should match the lowest range or the range most frequently used.

Can A Recording Milliammeter Be Used?

In applications where there is a chance that the use of a recorder might upset circuit conditions, the proposed installation can be easily tested. An indicating meter can be inserted into the circuit together with enough series resistance to bring the total resistance of the indicator and series resistor combination equal to that of the recorder under consideration. The diagram below illustrates this simple procedure.



If the indicator and resistance combination upsets the circuit, or if the indicator's readings are too low to be useful, it is recommended that the Esterline-Angus recording DC microammeter be used.

The E-A Recording DC Microammeter

This instrument is a combination of the E-A 0-1 milliampere recorder, and a specially designed magnetic amplifier. The basic range is 0-50 microamperes DC, with ranges of 0-50/100/200 millivolts also included. The instrument has the added versatility of being a recording 0-1 milliammeter when the amplifier is bypassed. Input resistance is approximately 200 ohms for the 50 microampere and 10 millivolt ranges, and is 1000 and 4000 ohms, respectively, for the 50 and 200 millivolt ranges. Response time of 1 second is independent of external circuit resistance.

FIG. 10—*The Oxyhemograph (Photocon Research Products, Pasadena, California) records oxygen content of the blood. The ear device is a photocell which reacts to blood color*

This instrument meets all of the requirements for applications demanding extra-sensitivity, stability, linearity, long-time reliability, and freedom from zero drift. It can be used with photoelectric cells, vibration pick-ups, strain gages, thermocouples, and other primary detecting devices. It can be used for research in numerous areas such as medical electronics and nucleonics. And, it can be set for center zero operation for such uses as null detection in bridge circuits. These examples are but a sampling of the many types of applications this instrument will accommodate. For complete details, refer to Catalog Section 41.

Micro-microampere Measurements

For applications where even smaller currents are to be measured, it is suggested that the use of Esterline-Angus DC milliammeters with General Radio Company's DC amplifier No. 1230AE be considered. Use of this amplifier permits recording of currents in the micro-microampere range. This amplifier and electrometer also measures millivolts and megamegohms. It can be supplied in an Esterline-Angus case to match the recorder. For further information, contact the General Radio Company, 275 Massachusetts Avenue, Cambridge, Massachusetts.

Model AW Direct Current Milliammeters

Permanent-Magnet, Moving-Coil Measuring Elements Nos. 421, 422, 423 and 424.
On circuits above 800 volts, one side of circuit must be grounded and recorder installed at ground potential.

Single Range Instruments

Range In MA	Measuring Element Number	Full Scale Volts[a]	Resistance In Ohms	Power Consumption In Milliwatts	Ohms In External Circuit for Critical Damping	Swinging Time (Seconds, One Way)					
						Critically Damped	With External Circuit Resistance of				
							10 Ohms	100 Ohms	1,000 Ohms	10,000 Ohms	100,000 Ohms
0-1	424	1.4	1400	1.4	50,000	0.5	5.0	4.0	3.0	1.0	0.5
0-2	424	7.0	3500	14.0			1.2	1.2	1.2	1.0	1.0
0-3	424	7.0	2330	21.0			1.2	1.2	1.2	1.1	1.1
0-5	421	0.35	70	1.7	4,000	0.5	4.0	3.0	0.8	0.5	0.5
0-10	421	2.0	200	20.0			1.2	1.1	1.0	0.8	
0-25	421	2.0	80	50.0			1.2	1.1	1.1	1.0	
0-50	422	0.05	1.0	2.50	25	0.5	1.0	0.5	0.5	0.5	
0-100	422	0.20	2.0	20.0			1.0	0.8	0.8		
0-150	423	0.018	0.12	2.7	2	0.5	0.5	0.5	0.5		
0-250	423	0.1	0.40	25.0	over 10	0.5	0.5	0.5	0.5		
0-500	423	0.1	0.20	50.0			0.8	0.8	0.8		
0-1000	423	0.1	0.10	100.0			1.0	1.0			

Multi-range Instruments

The measuring element used in multi-range milliammeters is determined by the lowest range to be included. Where the lowest range is below 0-5 MA, the 424 measuring element is used. If the lowest range is 0-5 MA or higher, No. 421 is used. Measuring elements Nos. 422 and 423 are not used in multi-range instruments. Multi-range meters have only two terminals, the various ranges being obtained with a tap switch, usually mounted in the case.

Range In MA	Full Scale Volts[a]	Resistance In Ohms	Power Consumption In Milliwatts	Ohms In External Circuit For Critical Damping	Swinging Time (Seconds, One Way)					
					Critically Damped	With External Circuit Resistance of				
						10 Ohms	100 Ohms	1,000 Ohms	10,000 Ohms	100,000 Ohms
WITH NO. 424 (0-1 MA) ELEMENT										
0-1	1.4	1400	1.4	50,000	0.5 sec.	5	4	3	1.0	0.5
0-2	7	3500	14			1.2	1.2	1.2	1.0	1.0
0-3	7	2330	21			1.2	1.2	1.2	1.1	1.1
0-5	7	1400	35			1.2	1.2	1.2	1.2	1.2
0-10	7	700	70			1.2	1.2	1.2	1.2	
0-25	7	280	175			1.2	1.2	1.2	1.2	
0-50	7	140	350			1.2	1.2	1.2	1.2	
0-100	7	70	700			1.2	1.2	1.2		
WITH NO. 421 (0-5 MA) ELEMENT										
0-5	0.35	70	1.7	4,000	0.5 sec.	4	3	0.8	0.5	0.5
0-10	2	200	20			1.2	1.1	1.0	0.8	
0-25	2	80	50			1.2	1.1	1.0	1.0	
0-50	2	40	100			1.2	1.2	1.1	1.1	
0-100	2	20	200			1.2	1.2	1.2		
0-250	2	8	500			1.2	1.2	1.2		
0-500	2	4	1000			1.2	1.2	1.2		

[a] In those instances where there is objection to the voltage drop shown for those ranges above the basic range, direct shunting can be employed, reducing the drop on all ranges to 1.4 volts on meters using basic element No. 424, and 0.35 volts on No. 421. Note, however, that this increases the damping, the swinging time of all shunted ranges being 3 to 5 seconds.

Charts—Uniformly divided, 4300 series, refer to Catalog Section 90.

Scales—To match any 4300 series chart. On multi-range meters, scale should match the lowest or the most used range. Select scale so multiplying factors can be applied easily. Normal values to be recorded should be from about ½ to ¾ full scale and maximum values less than full scale.

Zero—Normal calibration is left-hand zero. Shifting to center zero cuts in half the current for full scale in either direction. Center zero meters may be shifted to left-hand zero and operated up to full scale without overloading the measuring circuit.

Multi-ranges—No. 424 measuring element can be supplied with ranges between 0-1.0 MA and 0-1.0 ampere. No. 421 measuring element can be furnished with ranges from 0-5.0 MA to 0-2.0 amperes. See "Multi-range" heading page 4 for caution about voltage drop on high current ranges. Where the lowest range is 0-150 MA, use DC Ammeters and appropriate shunts, see Catalog Section 40. Voltage ranges can be combined with milliampere ranges in the same instrument.

Leads—None furnished. Lead resistance is not critical.

Binding Posts—Regularly furnished on portables.

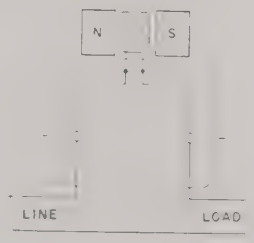
Damping—Eddy current type; variable by adjustment of external circuit resistance, see Figs. 5 and 8.

Response Speed—See tables above and Figs. 5 and 8.

Guaranteed Accuracy—1% of full scale current.

Dielectric Test—Single range meters, 5000 volts; multi-range, 2500 volts, 60 cycles for one minute.

Special Ranges—Intermediate milliampere ranges can be supplied. Meters with one or more milliampere ranges can also be equipped with one or more voltage ranges.



Internal wiring diagram of DC milliammeter

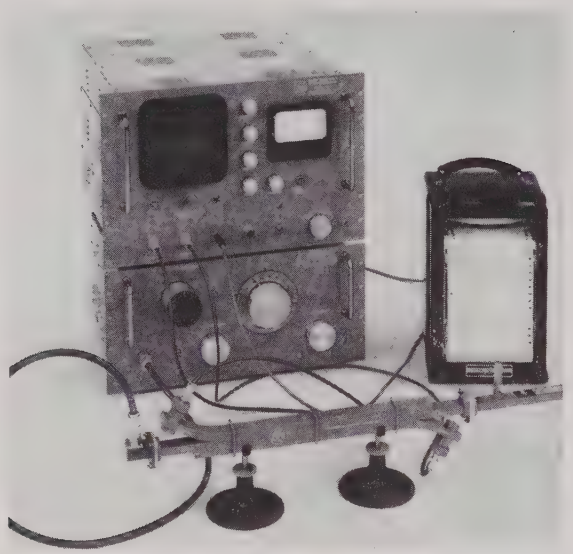


FIG. 11—*The equipment above, by California Technical Industries, Belmont, California, incorporates a recording DC milliammeter to chart voltage standing wave ratio (VSWR) during microwave and antenna tests*

Cases

Portable, wall, flush and front switchboard single cases are available and all but portable are also furnished in twin mounting. Flush cases have 120 volt, 60 cycle fluorescent lighting. For further information refer to Catalog Section 15.

Chart Drives

Esterline-Angus makes a number of different chart drives. These are divided into three general classes: hand-wound spring, motor-wound spring, and synchronous. Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. The change from inches per hour to inches per minute can be made manually by means of a shift lever or electrically with the addition of a shift coil inside the chart drive. High chart speed attachments which can provide speeds of ¾, 1½, and 3 inches per second are also available.

When instruments are combined in twin cases, both charts can be driven by a single chart drive mounted in the right-hand half of the twin. The other half of the twin then uses a slave mechanism called a phantom chart drive. Phantom drives can also be used where it is desired to drive the chart from an external source. Refer to Catalog Section 20.

How to Order—*Specify:*

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall Mounting.

2—Chart Drive (Catalog Section 20): Hand-wound spring, Motor-wound spring, Synchronous. If electric give voltage and frequency. If electric hour-to-minute feed shift desired, give voltage and frequency.

3—Measuring Element: Full scale milliamperes of the ranges desired. Left-hand or center zero.

4—Scale and Chart: Range numbers desired on chart and scaleplate. Chart speed.

5—Accessories and Attachments (Catalog Section 80): Writing door, glass corner in case cover, chart inspector, carrying case, right-and left-hand chronograph pens (give voltage and frequency), etc.

6—Supplies (Catalog Section 90): Extra pen elements, pen points, charts, ink.

Chronograph Pens

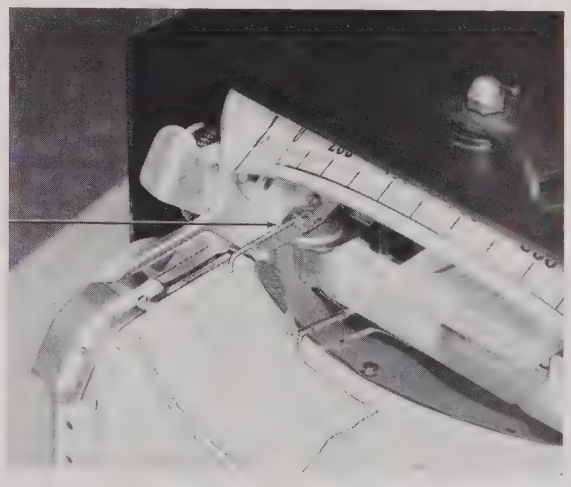


FIG. 12—*The chronograph pen illustrated is a highly useful "extra." One pen can be mounted to record in each margin of the chart. These devices will key other events to the main record. They are operated by a rugged electromagnet which can be rated for AC or DC voltages*

THE ESTERLINE-ANGUS COMPANY

Pioneers in the Manufacture of Graphic Instruments

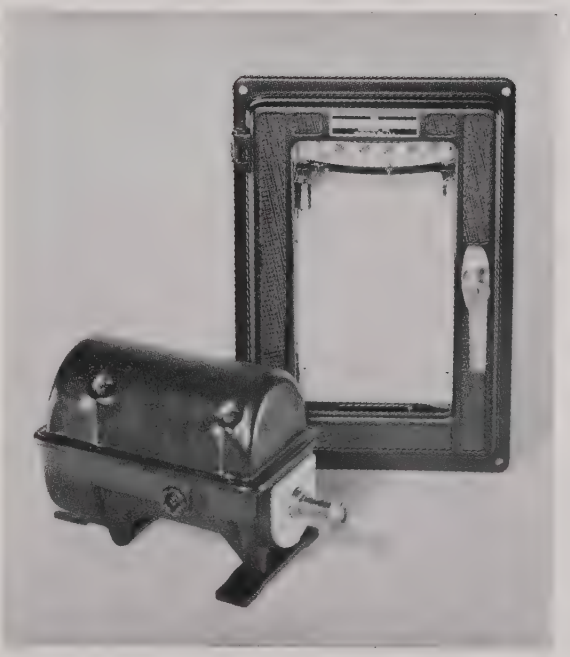
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

ESTERLINE-ANGUS

Recording

ELECTRIC TACHOMETER

Speed is the symbol of modern industry. Thus whether it is a function of the performance of a machine or vehicle, or its effect is an important factor in the control of production rate, cost, quality, or safety, its accurate measurement is a necessity. The Esterline-Angus Recording Electric Tachometer provides an indisputable permanent record of speed and graphically illustrates the uniformity and continuity of an operation as well. The result of over fifty years of instrument "know how," this speed recording system is designed for rugged industrial use yet provides the accuracy expected of laboratory equipment.



Catalog Section 46
(December 1959)

RECORDING ELECTRIC TACHOMETER

Catalog Section 46

SPEED is of primary interest to management and employee alike because of its importance as a function of machine and vehicle performance in relation to production control, operator efficiency and safety. Steam turbines, rolling mills, pumps, blowers, stirrers, presses and marine engines are but a sampling of the multitude of machines used in operations where speed is an important factor. As with any variable that affects performance, speed must be accurately measured before it can be properly evaluated. In addition, evaluation calls for knowledge as to "when "as well as "how fast." The Esterline-Angus electrical speed recording system provides both of these answers accurately and clearly. The graphic record gives proof of uniformity and continuity of an operation as well. The record can be filed for purposes of analysis and comparison at a later date. There is no guesswork involved when the chart is at hand to give indisputable answers.

There are sound reasons why the electrical method of recording and measuring speed has been generally approved and adopted by engineers. The indicating or recording element may be located at a distance from the point of measurement; a number of indicators, recorders or control relays may be actuated at the same time and at different points. The calibration of the electrical tachometer is easily checked.

The Esterline-Angus electrical speed recording system was designed for rugged industrial use and will stand up to the abuse that may be encountered in steel mills, cement plants, paper mills, chemical works, etc. This ruggedness of construction also contributes to the stability and accuracy of the generator output voltage. All parts are designed to give years of trouble-free service. They are held in proper alignment by the sturdy case. The result is continued accuracy.

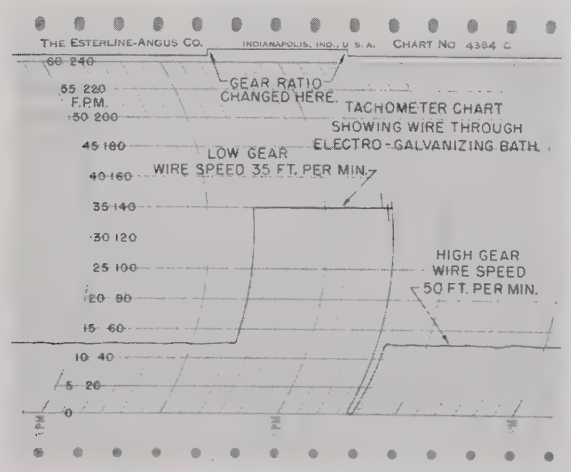


FIG. 1—*Thickness of zinc coating on steel wire is monitored by recording wire speed through galvanizing bath. Chronograph pen shows which of two speed ranges is in use on galvanizing machine*

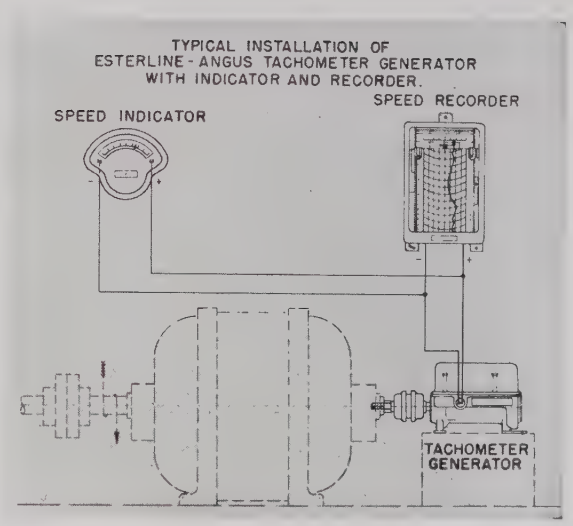


FIG. 2—*Wiring diagram of typical speed-measuring installation, consisting of generator, recorder and indicator, with generator directly coupled to electric motor*

Esterline-Angus has manufactured speed recording equipment for over 50 years. The line consists of:

(a) A specially designed, permanent-magnet DC generator which produces a voltage directly proportional to the speed at which the armature is driven, and which reverses output polarity with a reversal in drive shaft rotation.

(b) A strip-chart graphic DC voltmeter actuated by voltage from the DC generator and calibrated to record speed in revolutions per minute, feet per minute, miles per hour, or other desired units.

(c) Pulleys, 2-inch and 4-inch, for flat belt drives. Dimensions are given in Fig. 7.

(d) A flexible coupling of the pin and leather disc type. Dimensions are given in Fig. 7.

(e) A calibrated direct reading relay which can be set to open or close an electrical circuit at any given speed when used in connection with the generator.

(f) Indicating instruments manufactured by others but supplied by Esterline-Angus which can be used in place of or in addition to a speed recorder or relay.

A typical Speed Recorder installation is pictured in Fig. 2. Here the Tachometer Generator has been coupled to a motor by means of the E-A flexible coupling. The output of the generator is fed to the recorder which has been paralleled with an indicating voltmeter. Other methods of coupling are illustrated in Fig. 6.

About the Generator

Electrical Characteristics

All Esterline-Angus generators are of the DC type and are calibrated to develop an open circuit EMF of 25 volts at 1000 RPM of the armature. This calibration is adjusted to an accuracy of ¼% or better by means of a movable magnetic shunt attached to the generator pole pieces. This shunt is capable of varying the generator voltage output over a range of approximately 3% each way.

The relation between the speed being measured and the generated voltage is a "straight line" over the entire permissible speed range of the generator, 50 to 5000 RPM (100 to 5000 RPM when generator load current exceeds 10 milliamperes). Internal resistance of the generator is 25 ohms ±2 ohms. The rated current capacity is 50 milliamperes.

The generator is sensitive to direction of drive shaft rotation since the output is DC and reverses polarity with a reversal in direction of rotation. Thus center zero records showing forward and reverse speeds can be taken of the performance of such equipment as rolling mills, marine engines, cranes and hoisting machinery.

The high output voltage of the generator permits the use of relatively high resistance recorders thereby reducing temperature effects. There is no appreciable temperature error over the range of −20° to +150°F. Also because of this high output voltage, very rarely is it necessary to make an allowance for lead resistance between the generator and instruments. The 22-segment commutator produces a DC voltage in which the RMS value of the ripple is less than 2% of the output. Under normal circumstances, the ripple is of no significance and can be ignored. However, for electronic applications, it can be eliminated by introducting a simple 1000 ohm-5 microfarad resistance-capacitance filter in the output circuit.

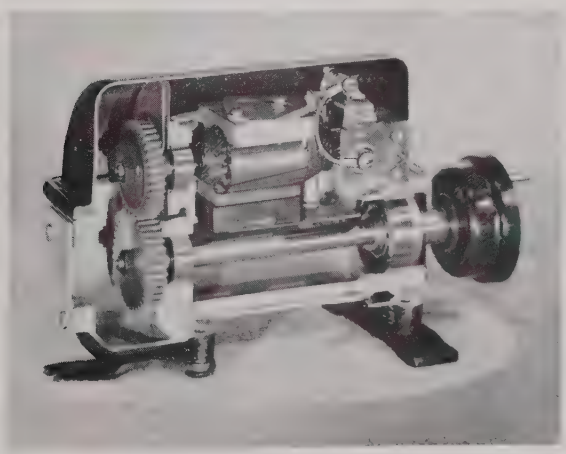


FIG. 3—*Cut-away view of Tachometer generator showing details of inner construction. Notice gears in separate compartment, and large sealed bearings on each shaft*

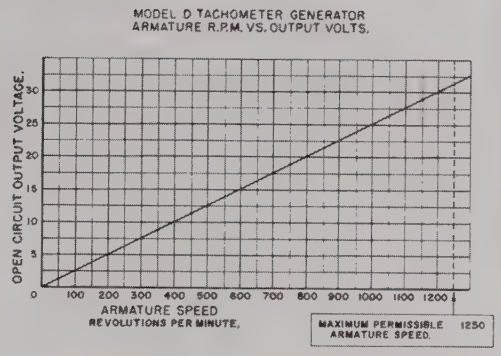


FIG. 4—*The Esterline-Angus tachometer generator is designed to provide a "straight line" relation between generated voltage and speed. This feature is illustrated by the graph above. Note that the generated open circuit EMF is 25 volts at 1000 RPM of the armature*

Mechanical Characteristics

The external appearance of the generator is shown on the front cover. The case is made in two pieces. The upper half is a drawn brass cover which when removed, permits easy access to all of the internal mechanism. The lower portion is a light but rigid aluminum casting which holds all parts in accurate alignment.

The rugged drive shaft extending through the case is ⅝" in diameter and is carried on a pair of double sealed ball bearings which do not require lubrication. The drive shaft is fitted with a No. 5 Woodruff key and is threaded ⅝-18 NF and is connected to the armature shaft by internal gears as shown in the cut-away view Fig. 3. This built-in gearing makes possible the wide full scale drive shaft speed range of 50 to 5000 RPM. The gears are in a separate compartment which is sealed off by a felt gasket. The internal gear combinations used are 1:1, 1:1½ and 1½:1, 1:2 and 2:1, 1:3 and 3:1, 1:4 and 4:1, 1:5 and 5:1, 1:6 and 6:1.

The armature is also carried on double sealed ball bearings which do not require lubrication. It rotates in a dense magnetic field produced by an Alnico V magnet which has been aged to insure perfect stability of generator output voltage. Since the field is produced by a permanent magnet, this generator, unlike the separately-excited type, requires no electrical excitation and thus does not have its accuracy affected by changes in exciting voltage.

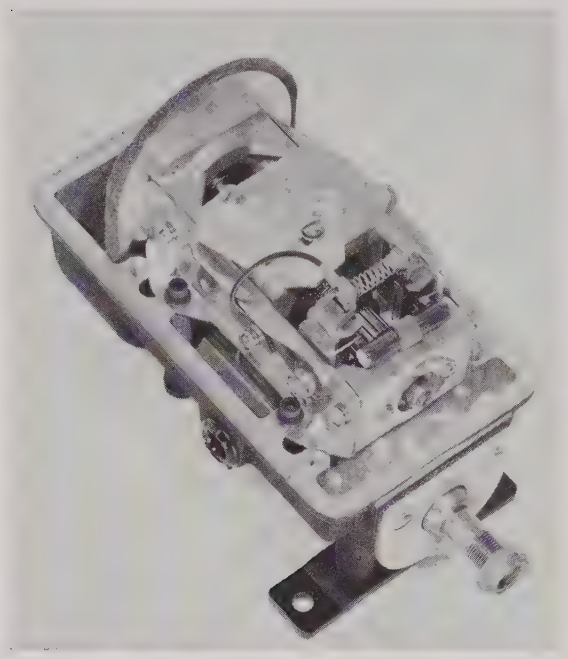


FIG. 5—*View of tachometer generator with cover removed. Simple replacement of brushes is possible because of easy accessibility to all inner parts*

The armature is of the slotted iron core type and is made up of a number of laminations produced from the finest grade of electrical steel. The winding is fully protected in the slots and insulated to withstand a dielectric test of 1100 volts AC for one minute. The commutator and brush system has been designed so that wear is confined to the brushes. The commutator segments are glass hard. The brushes are a special alloy which provide for brush-commutator lubrication.

To withstand the rigors of rugged industrial applications, the generator has been further protected by the use of a sealing gland on the drive shaft and gaskets on all other openings including the small end plates. These features make the generator dust, fume and water tight. It is not, however, classed as explosion proof. The drive shaft carries centers at each end so that its speed can be checked by means of a revolution counter and stop watch.

Generator Installation Data

Years of experience have shown that care should be exercised in making the original installation of the generator, and that it should then not be disturbed as long as it continues to perform satisfactorily.

Mounting—Servicing operations are more easily performed and parts are more easily accessible when the generator is mounted on a horizontal surface. In those cases where it is necessary to mount it vertically, it is preferable to have the drive shaft at the top to minimize the possibility of oil or grease reaching the commutator.

Although the generator has been designed to withstand the vibrations associated with industrial machinery, it should be mounted so as to be as free of vibration as possible. The generator can be mounted directly on or against large masses of iron without affecting its calibration.

The housing is fitted with pressed steel feet which are used for most installations. For applications where a machined surface and accurately located mounting holes can be provided, the feet can be removed and the unit secured by means of four screws extending upward into the case. Dimensions are given in Fig. 7.

Drive Shaft Speed—Where the maximum generator burden is 10 milliamperes or less, the drive shaft speed may be as low as 50 RPM with the recorder and/or indicator at full scale deflection. If the current drain exceeds 10 milliamperes, the drive shaft speed at full deflection may be as low as 100 RPM. The maximum permissible drive shaft speed for continuous operation is 5000 RPM.

Torque—The torque required to drive the generator is small but varies considerably with the tightness of the seal which surrounds the drive shaft. With the sealing gland well worn in, this torque will average ¾ inch-pound at the drive shaft. For all practical purposes, torque is independent of the internal gear ratio.

Temperature Limits—The generator will perform satisfactorily in an area where the ambient temperature is in the range from −20° F. to +150° F.

Types of Generator Drives

A tachometer drive should be as simple as possible, should be positive, should have a constant ratio, and should be free from slip, whip, oscillation, or any other factor which might keep the generator speed from being an accurate replica of the speed being measured. Direct drive with flexible coupling fills all of these requirements. Where direct drive is not practical, either a simple spur gear drive or a flat endless belt usually is the next best means. A list of possible driving methods includes:

1. Direct connection by coupling
2. Driving through gears
3. Belt and pulley
   (a) Flat belt
   (b) V-belt
   (c) Spring belt
4. Chain drive
5. Flexible shaft

Direct Drive—For installations where direct connection to the driving shaft is to be used, we supply a flexible coupling of the pin and leather disc type, especially designed for use with this generator. The dimensions for this coupling are shown in Fig. 7. This unit will take care of ordinary lateral or angular misalignment, and will permit a maximum of ½ inch longitudinal motion between the generator and the driving shaft. It can be furnished for clockwise, counterclockwise, or reversing shaft rotation.

In cases where the generator is connected to a shaft which is free to move about, as in the case of the "fly roll" of a paper mill, the connection can often be made by using a short length of rubber hose as a coupling, since this permits a considerable lateral displacement between the driving and the driven shafts.

Gear or Belt Drive—Where the end of the driving shaft is not accessible, or where the generator cannot be mounted in line with the shaft whose speed is to be measured, or where the maximum speed of this shaft is below 50 RPM or above 5000 RPM, either a gear or a belt drive is recommended. If the generator can be placed close enough to the driving shaft, a simple spur gear drive is recommended. Gears provide a drive that is positive, the ratio is definite, and they will operate in spite of some misalignment. They should be enclosed or guarded.

If the generator must be located too far from the driving shaft to permit the use of gears, then a belt and pulley drive should be used, provided the maximum belt speed does not exceed about 4000 FPM. We recommend the use of a flat belt about 1 inch wide, either single-ply leather or woven fabric. The belt should be endless, containing no lacing or fasteners, since the passage of these over the pulley will cause a cyclic fluctuation in the generator speed. The pulleys should have only a slight crown and should be flanged. Fig. 7 gives dimensions of our 2-inch and 4-inch pulleys for flat belt drives. If some other make of pulley is employed, and particularly if it is of large diameter, we recommend that it be made of aluminum in order to reduce the weight, and that it be dynamically balanced. A belt drive is preferable in cases where the generator is to be driven by a machine which is subject to vibration. The generator should be mounted on a separate, non-vibrating support.

Drive by means of a V-belt is recommended only where other methods of driving are not feasible. It has the objection that the pulley ratio is somewhat uncertain. As the belt changes due to wear or the result of temperature or moisture, it will ride higher or lower in the groove of the pulley thereby altering the drive ratio. If this drive must be used, large pulleys of a 1:1 ratio give the best results. Notched

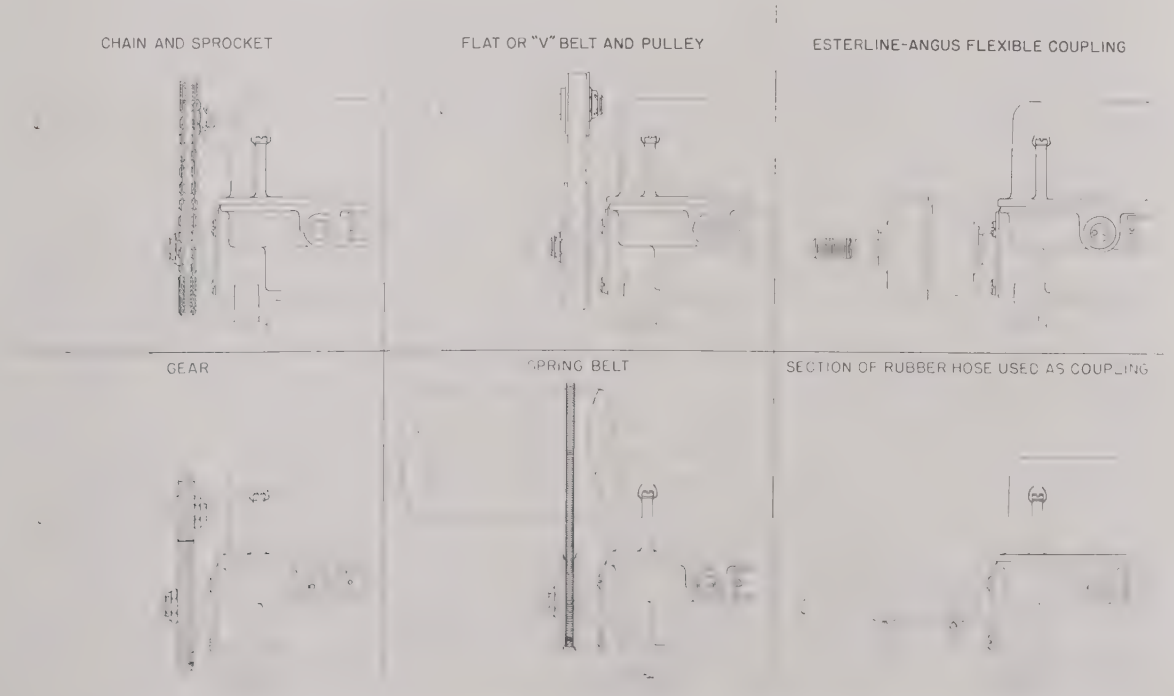


Fig. 6—*Six possible methods of driving the tachometer generator are illustrated in the sketches above. Best performance will result if care is exercised in making the original installation. Guarding should be provided for maximum safety*

belts which use special pulleys may overcome the above difficulties.

Where the driving pulley is a large steel shaft such as the shaft on a water wheel generator, a spring belt drive can often be applied. If proper tension is applied, the belt will not slip even in the presence of oil or grease.

Chain Drive—In some respects, the chain drive combines the characteristics of gear and belt drive. It permits long distances between centers, is a positive drive and has a definite ratio. It has the disadvantage that the chain may whip at certain speeds causing cyclic fluctuations in generator speed. Unless the chain is enclosed, foreign material may find its way into the drive causing excessive wear or damage.

Flexible Shaft Drive—Like the V-belt, the flexible shaft drive is restricted to special applications. The elasticity of this drive when added to the inertia of the rotating parts of the generator comprises a coupling in which oscillation is apt to occur. This effect increases with the length and flexibility of the shaft. This drive is usually restricted to portable applications, or for connection to shafts which rotate about movable centers. The flexible shaft should be made as short as possible and as stiff as is consistent with the angle through which it must be bent.

Friction Drive—A friction drive is one in which speed is transmitted to the generator through a friction wheel which contacts a rotating shaft, another wheel, or material being produced. The drive has the disadvantage of changing drive ratio due to wear of the friction wheel.

Electrical Connections

A hole threaded for ½″ conduit is provided on either side of the generator case. A 2-hole bakelite bushing and a ½″ pipe plug are provided with each generator. If the local electric code permits and the generator is located in a clean, dry, nonhazardous location, open wiring may be brought into the case through the bushing. Under less favorable conditions, it will be preferable to use conduit or BX cable.

Normally, the resistance of the wiring between the generator and the instruments is not critical because it is such a small part of the total circuit resistance. In most cases the current drawn from the generator is less than 10 milliamperes thus permitting the use of No. 14 wire for distances up to 1000 feet between generator and instruments. Greater wiring distances and/or higher currents can be accommodated if complete information is provided when ordering.

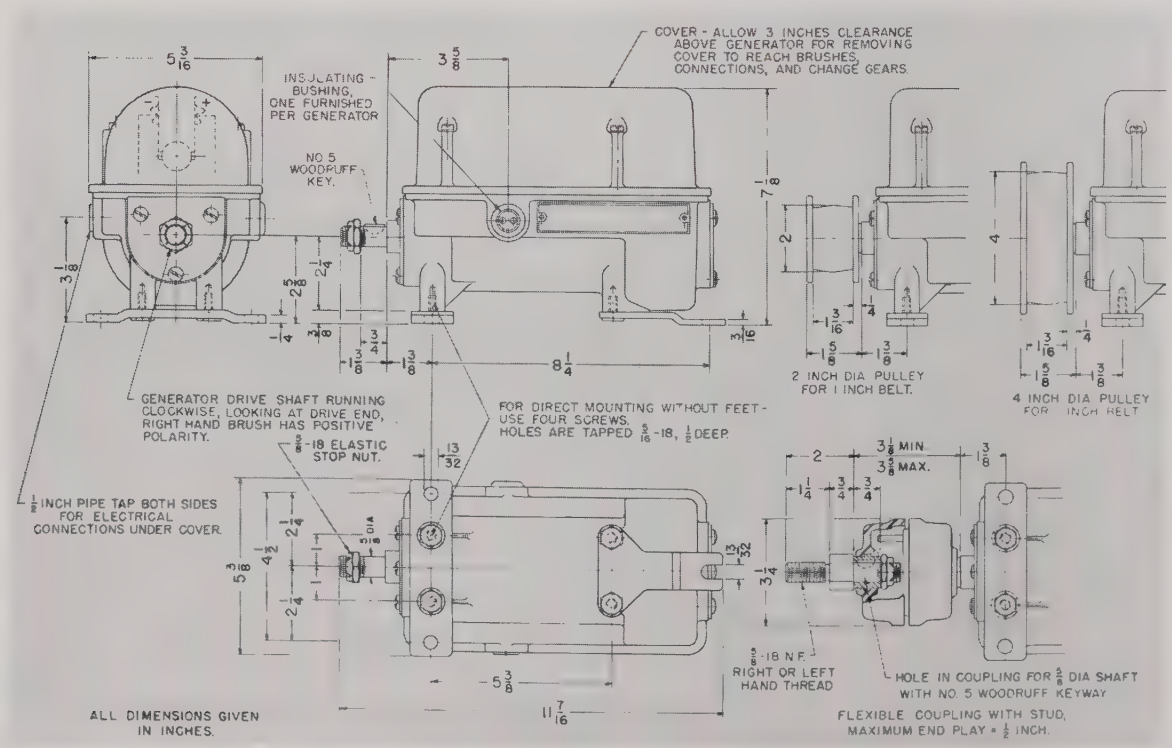

COVER - ALLOW 3 INCHES CLEARANCE ABOVE GENERATOR FOR REMOVING COVER TO REACH BRUSHES, CONNECTIONS, AND CHANGE GEARS.
INSULATING BUSHING, ONE FURNISHED PER GENERATOR
NO. 5 WOODRUFF KEY.
2 INCH DIA. PULLEY FOR 1 INCH BELT.
4 INCH DIA. PULLEY FOR 1 INCH BELT
GENERATOR DRIVE SHAFT RUNNING CLOCKWISE, LOOKING AT DRIVE END, RIGHT HAND BRUSH HAS POSITIVE POLARITY.
FOR DIRECT MOUNTING WITHOUT FEET - USE FOUR SCREWS. HOLES ARE TAPPED 5/16-18, 1/2 DEEP.
10-18 ELASTIC STOP NUT.
1/8 INCH PIPE TAP BOTH SIDES FOR ELECTRICAL CONNECTIONS UNDER COVER.
10-18 N.F. RIGHT OR LEFT HAND THREAD
HOLE IN COUPLING FOR 3/8 DIA SHAFT WITH NO. 5 WOODRUFF KEYWAY
ALL DIMENSIONS GIVEN IN INCHES.
FLEXIBLE COUPLING WITH STUD, MAXIMUM END PLAY = 1/2 INCH.

FIG. 7—*Outline and mounting dimensions of Esterline-Angus Model D tachometer generator. Mounting feet can be removed when mounting on a machined surface*

About the Recorder

The recording instrument consists of a powerful, accurate, DC measuring element, a chart driving mechanism and a die cast aluminum case housing the assembly. The guaranteed accuracy of the recorder is 1% of full scale, and the guaranteed accuracy of the combination of generator and recorder is 1¼% of full scale. Speed recorder scales are linear.

The time required for the pen on a standard recorder to move from any point on the chart to any other point will not exceed one second.

Measuring Elements—The measuring elements used in Esterline-Angus Speed Recorders are of the permanent-magnet moving-coil type. The recorder designed for most applications is a DC Voltmeter which uses a measuring element requiring 5 milliamperes for full scale deflection and thus has a 200 ohm per volt sensitivity. A 1000 ohm per volt (1 milliampere measuring element) recording voltmeter is recommended where it is to become a part of an existing speed measuring system or where it is to be switched on or off, as it will not appreciably affect the readings of other instruments on the system.

Multiple range recorders can be furnished but ratio between highest and lowest ranges may not exceed 4:1, assuming generator gears are not changed.

Recorder Cases—Portable, wall, flush and front switchboard single cases are available and all but portable are also furnished in twin mounting. Flush cases have 120 volt, 60 cycle fluorescent lighting. For further information refer to Catalog Section 15.

Types of Chart Drives—Esterline-Angus makes a number of different types of chart drives. These include hand-wound spring drives, motor-wound spring drives and synchronous motor drives, which provide speeds of ¾, 1½, 3, 6 or 12 inches per hour and per minute. The change from inches per hour to inches per minute can be made manually by means of a shift lever or electrically with the addition of a shift coil inside the chart drive. High chart speed attachments which can provide speeds up to 3 inches per second are also available.

FIG. 9—*Illustrated above is a speed recorder with wall case that can be fastened to any flat vertical surface. A mounting and wiring compartment is attached to the back of the case body*

When instruments are combined in twin cases, both charts can be driven by a single chart drive, mounted in the right-hand half of the twin. The other half of the twin then uses a slave mechanism, called a phantom chart drive. Phantom drives can also be used where it is desired to drive the chart from an external source. Refer to Catalog Section 20.

Indicating Instruments—An indicating voltmeter, properly calibrated and connected to the terminals of the E-A tachometer generator, becomes a speed indicator. Such instruments can be used with or without recorders or relays and a number of them can be operated from a single generator.

We recommend the use of high-resistance (500 ohm per volt) indicators. For easy readability, a scale length of 6 to 14 inches is normally suggested. We can furnish most makes and styles of indicators.

Speed Relays—For applications where it is desired that apparatus or operations be controlled in relation to speed, an accurate reliable contact-making instrument sometimes called a speed relay is available. Refer to Catalog Section 70.

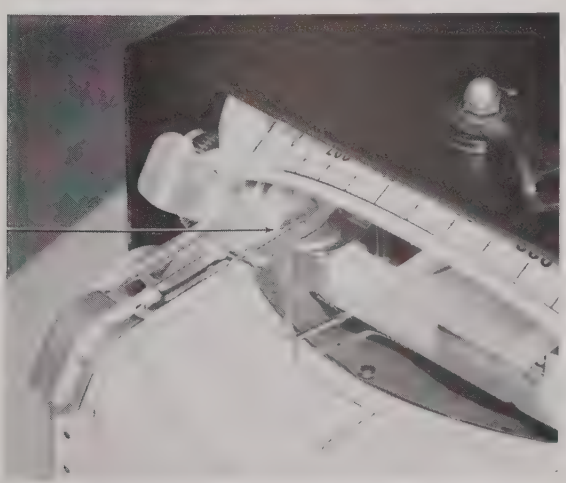


FIG. 8—*The chronograph pen illustrated is a highly useful "extra." One pen can be mounted to record in each margin of the chart. These devices will key other events to the main record. They are operated by a rugged electromagnet which can be rated for AC or DC voltages*

Summary of Specifications

MODEL D TACHOMETER GENERATOR

Voltage Output—25 Volts DC open circuit at 1000 RPM of armature. A straight line relation of generated voltage vs armature speed. See Fig. 4. Reverses polarity with reverse in direction of armature rotation. Can be adjusted by magnetic shunt ±3%.

Speed Limits—Drive shaft speed limits for full scale deflection with generator burden of 10 milliamperes or less.
50 to 5000 RPM
Above 10 milliamperes
100 to 5000 RPM
(Armature Speed limit 1250 RPM)

Current Capacity—50 Milliamperes DC

Internal Resistance—25 ohms ±2 ohms

Temperature Limits—Minus 20° to plus 150° F

Internal Gear Ratios—1:1, 1:1½ and 1½:1, 1:2 and 2:1, 1:3 and 3:1, 1:4 and 4:1, 1:5 and 5:1, 1:6 and 6:1.

Dielectric Test—1100 volts AC for one minute between armature winding and grounded case.

Torque—Required torque averages ¾ inch-pound and for practical purposes is independent of internal gear ratio.

MODEL AW SPEED RECORDER

Measuring Element—Permanent-magnet moving-coil type calibrated as a DC voltmeter with 200 ohm per volt sensitivity (5 milliamperes full scale). 1000 ohm per volt sensitivity (1 milliampere full scale) available for special applications. Refer to page 7.

Case—Several types available as described on page 7 and catalog section 15.

Chart Drive—Many types available as described on page 7 and catalog section 20.

Charts—Uniformly divided, 4300 series, refer to catalog section 90.

Scales—To match any 4300 series chart.

Multiple Ranges—Can be supplied but ratio between highest and lowest ranges may not exceed 4:1 assuming generator gears are not changed.

Zero—Left hand or center zero can be furnished.

Accuracy—1¼% when used as a Speed Recorder with E-A Tachometer Generator. 1% when used alone as a DC Voltmeter.

Temperature Limits—Plus 20° to plus 120° F.

Response Speed—Time required for pen to move from any point on chart to any other point not to exceed one second.

Dielectric Test—5000 Volts, 60 cycles, for one minute.

How to Order—*Specify*

1—SPEED OF GENERATOR DRIVE SHAFT AT FULL SCALE ON INSTRUMENTS.

2—Esterline-Angus coupling if required. Is coupling stud to have right-hand thread, or left-hand thread; or right-hand thread with jam nut (reversing shaft rotation)? Refer to Fig. 7.

3—Esterline-Angus pulleys if required. 2 inch or 4 inch? Refer to Fig. 7.

4—Recorder case style (Catalog Section 15): Portable, Flush switchboard, Front switchboard, Wall mounting.

5—Recorder chart drive (Catalog Section 20): Synchronous motor, Hand-wound spring, Motor-wound spring or other. If electric give voltage and frequency. If electric hour-to-minute shift desired, give voltage and frequency.

6—Chart and recorder scale (Catalog Section 90): Range numbers desired on chart and scale. Chart speed.

7—Recorder accessories and attachments (Catalog Section 80): Writing door, glass corner in case cover, chart inspector, right- and left-hand chronograph pens (give voltage and frequency).

8—Recorder supplies (Catalog Section 90): Charts, extra pen elements, pen points, pen point cleaners, ink.

9—Indicator if required. If we are to furnish, state desired make, model, scale range and type of case. If indicator is not to be furnished by us, give full scale range and current of instrument to be used and we will advise proper full scale voltage calibration.

THE ESTERLINE-ANGUS COMPANY
Pioneers in the Manufacture of Graphic Instruments
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

Catalog Section 46
Printed in U.S.A., 15M

Product Representatives
in Most Principal Cities

ESTERLINE-ANGUS

Multi-purpose Recorders

AC-DC Ammeters
AC-DC Voltmeters
AC-DC Ammeter-Voltmeters
AC Ammeter-Voltmeters
AC Milliammeters

UNIFORM SCALES AND CHARTS

MULTI-PURPOSE recorders employ the familiar, rugged and reliable, permanent-magnet, moving-coil measuring element which is described completely in catalog sections 40 (DC Ammeters and Voltmeters) and 42 (DC Milliammeters). Coupled with this measuring element are silicon rectifiers to adapt it to AC measurements. The AC ranges of these instruments measure average values but are scaled in terms of RMS values of a sine wave.

The measuring element with rectifiers has a basic range of 0-50 MA AC, 50-800 cycles, (approximately 0-43 MA DC) to make possible current readings as low as 50 amperes full scale with the split-core current transformer shown on page 4. It is furnished in all of the following:

AC Milliammeter — AC Ammeter-Voltmeter
AC-DC Ammeter — AC-DC Ammeter-Voltmeter
AC-DC Voltmeter

A large variety of ranges can be added to the basic 0-50 MA range. Some of the more popular combinations of ranges are shown immediately below the tables on page 3.

Accuracy

Guaranteed accuracy on AC is 2% of full scale, with sine wave applied. When used on 60 cycle sine wave, the 0-150/300/600 volt AC ranges have an accuracy of 1%. Other wave shapes will cause some increase in error, but the normal variations encountered on commercial systems will seldom be large enough to affect the readings more than 1 or 2 percent.

DC voltage ranges have a guaranteed accuracy of 1% of full scale and DC millivolt ranges 1½%.

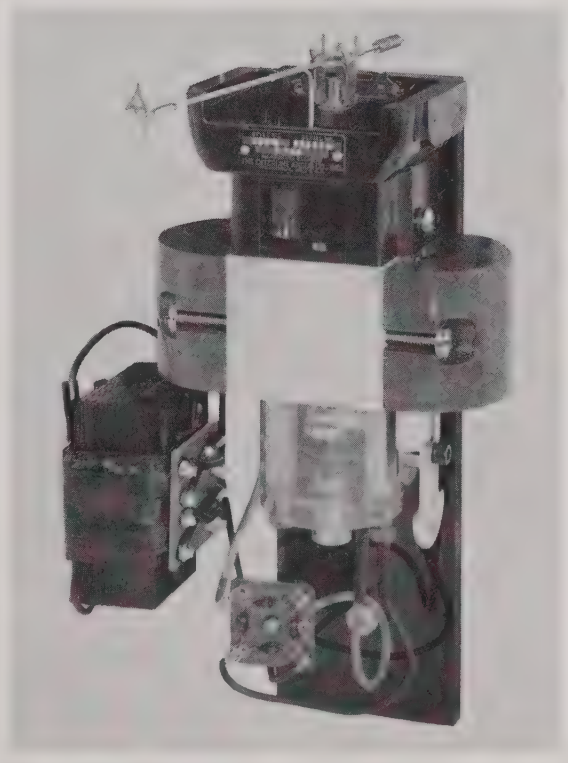


FIG. 1—*The multi-purpose recorder can be furnished with both AC and DC current and voltage ranges. This view shows the rugged permanent-magnet moving-coil measuring element, the rectifier mounting plate and the internal transformer with 50 MA secondary*

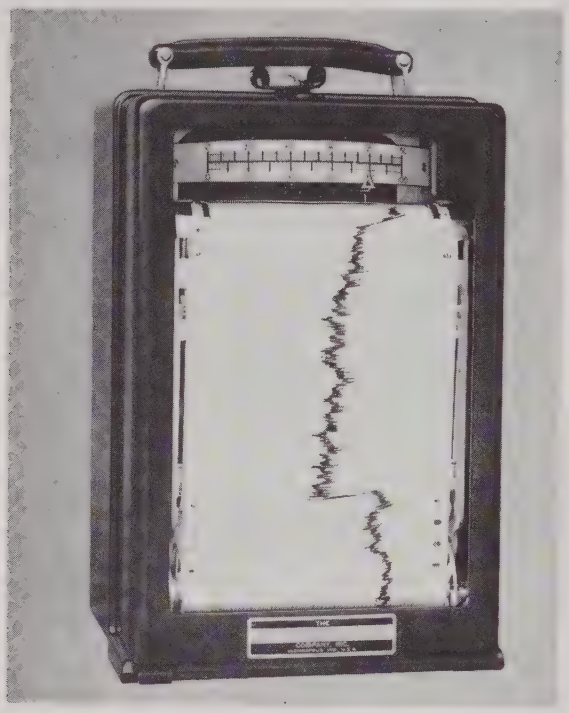


FIG. 2—*Multi-purpose recorders are usually supplied with dual scales, the most common being 0-150 and 0-100*

Current Transformers

The low burden of these instruments makes possible the use of a special split-core current transformer having a primary range as low as 50 amperes. The 5-ampere range of the multi-purpose recorder is usable with split-core current transformers having a 5-ampere secondary and primary ratings of 250† amperes or higher. Most closed-core switchboard current transformers can be used with these instruments on the 5-ampere range and, for portable service, the E-A Model D Universal current transformer extends the range of the instrument to 800 amperes.

(Additional details about the Model D and Split-core current transformers are given in Catalog section 80)

†The instrument is not usable with the 150 ampere range of the 150/300/600:5 split core transformer.

Low AC Voltage Measurements

A special portable step-up potential transformer makes possible 60 cycle voltage recordings with a full scale value as low as 5 volts. The transformer has primary ranges of 5, 15 and 30 volts and has a secondary rating of 150 volts 60 cycles. The transformer can be used with any multi-purpose recorder with an AC range of 150 volts. Intermediate ranges above 30 volts can be handled by taps on the recorder between 0-50 and 0-150 volts.

Scales and Charts

Series 4300 charts, uniformly divided along the arc, are used in these recorders. Multi-range instruments, such as AC-DC Voltmeters, should be scaled for the lowest range or the range that will be most widely used. Multi-purpose recorders, such as AC-DC Ammeter-Voltmeters, should have dual scales. Where a meter has both voltage and current ranges, it is general practice to use a scale having range numbers of 0-150 (if that is the lowest voltage range) and 0-100. The 0-150 range numbers can then be used with a

Continued on page 4

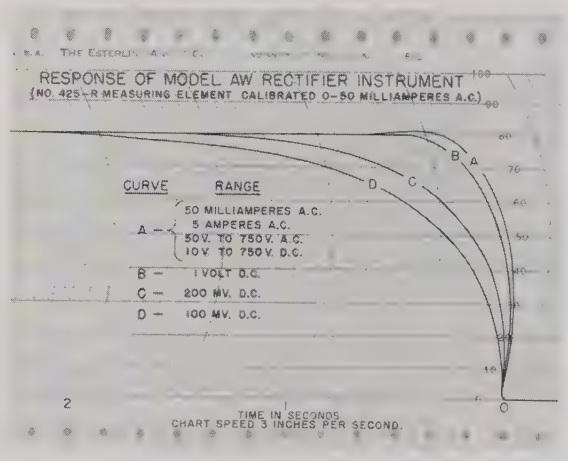
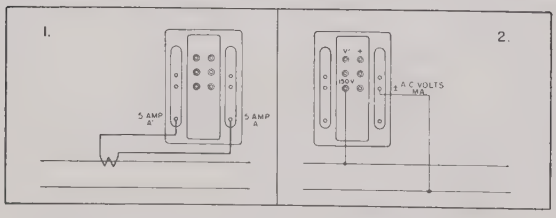

RESPONSE OF MODEL AW RECTIFIER INSTRUMENT
(NO. 425-R MEASURING ELEMENT CALIBRATED 0-50 MILLIAMPERES A.C.)
CURVE
RANGE
A —
50 MILLIAMPERES A.C.
5 AMPERES A.C.
50 V. TO 750 V. A.C.
10 V. TO 750 V. D.C.
B — 1 VOLT D.C.
C — 200 MV. D.C.
D — 100 MV. D.C.
TIME IN SECONDS
CHART SPEED 3 INCHES PER SECOND.

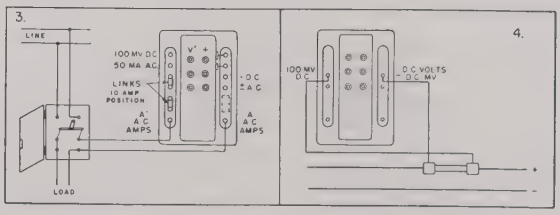
FIG. 3—*This family of curves shows the speed of response of measuring element No. 425-R on different ranges. The 0-50 MA base range of multi-purpose recorders completes its swing in less than ¾ second.*

These Connection Diagrams Demonstrate Some of the Many Uses



On the 5-ampere AC range, with a switchboard current transformer

Reading AC voltage



Connections made at a switch to record current directly on the 10-ampere range

With a shunt to record DC amperes

Model AW Multi-purpose Recorders

Measuring Element No. 425-R (50-800 cycles)

Ranges Available—*Single- or Multi-range*

AC Milli-ammeter	AC AMMETERS		VOLTMETERS (Approx. 10 ohms per volt AC, 20 ohms per volt DC)		
	Single Ranges Amperes	Double Ranges Amperes	AC	DC	
Milli-amperes			Volts	MV	Volts
0–50	0–1.0	0–1.0/2.0	0–50	0–100	0–1
	0–1.25	0–1.25/2.5	0–75	0–125	0–2
	0–2.0	0–2.0/4.0	0–100	0–150	0–5
	0–2.5	0–2.5/5.0	0–125	0–200	0–10
	0–4.0	0–5.0/10	0–150	0–300	0–25
	0–5.0		0–300	0–400	0–50
	0–10		0–600	0–500	0–100
			0–750	0–750	0–150
			0–800		0–300
					0–600
					0–800

Some Popular Combinations:

AC-DC Ammeter

0-50 MA*, 0-5 A AC; 0-100 MV DC
0-50 MA*, 0-2.5/5.0 A AC; 0-100 MV DC

AC-DC Voltmeter

0-150/300/600 V AC and DC.

AC Ammeter-Voltmeter

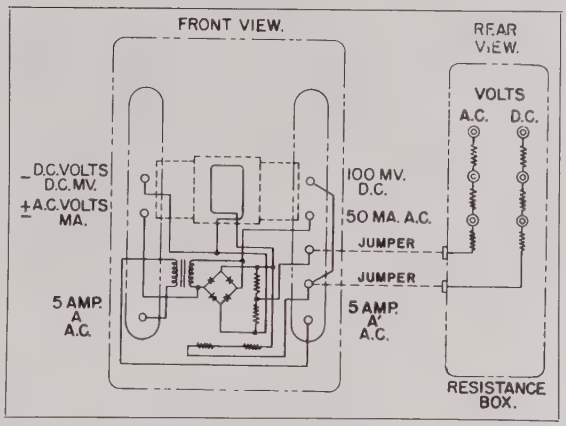
0-50 MA*, 0-2.5/5.0 A, 0-150/300/600 V.
0-50 MA*, 0-5.0/10 A, 0-150/300/600 V.

AC-DC Ammeter-Voltmeter

0-50 MA*, 0-5 A AC; 0-100 MV DC; 0-150/300/600 V AC & DC

0-50 MA*, 0-5.0/10.0 A AC; 0-100 MV DC; 0-150/300/600 V AC & DC (This group of ranges uses all available terminal spaces. See diagram 3.)

*0-50 MA range for use with split-core current transformer having 50 MA secondary. See page 4 and catalog section 80.



Internal connections of a multi-purpose recorder having ranges of 0-50 MA and 0-5 A AC, 0-100 MV DC and 0-150/300/600 Volts AC and DC

Charts—Uniformly divided, 4300 series, refer to catalog section 90.

Scales—To match any 4300 series chart.

Zero—Left-hand. Recorder has no polarity on AC ranges.

Leads—Two 5-foot leads furnished with portable recorders. Other case styles have screw terminals. Meters with a millivolt range require calibrated leads.

Intermediate Ranges—Any intermediate AC and DC voltage ranges can be furnished. Only the listed milliampere and ampere ranges are available.

Response Speed—See Fig. 3.

Dielectric Test—2500 volts, 60 cycles for one minute.

Accuracy—AC: 2% of full scale on sine wave; 150/300/600 volts, 60 cycles 1%. DC: Millivolts 1½%; volts 1% of full scale.

Overload Capacity—100% continuous overload on all current ranges; 10 times full scale for 1 second.

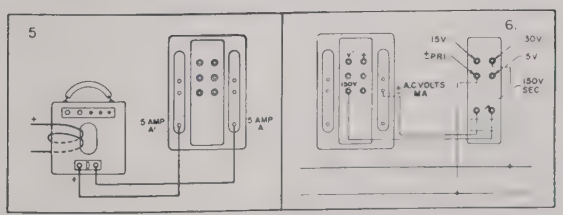
Burden—Less than 1.0 volt-ampere on current ranges. Sensitivity of AC voltage ranges is 10 ohms per volt; on DC voltage ranges sensitivity is 20 ohms per volt.

Current Transformers—Required above 50 MA and 5 amperes AC. Use only special split-core CT on 50 MA range (page 4). With 5-ampere range, use E-A Model D Universal CT, any good closed-core CT, or split-core CT with a primary range not less than 250 amperes.

Shunts—Required with 100 MV range.

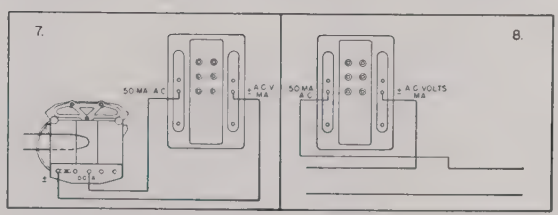
Step-up Potential Transformer—Record low 60 cycle voltages with 5/15/30:150 volt 60 cycle transformer (Page 4).

of Multi-purpose Recorders Having Both AC and DC Ranges



With a Model D, Universal current transformer on a through range

With step-up potential transformer to record low 60 cycle voltages



With split-core CT, 50 MA secondary, designed especially for use with these recorders

As an AC milliammeter connected directly in the line

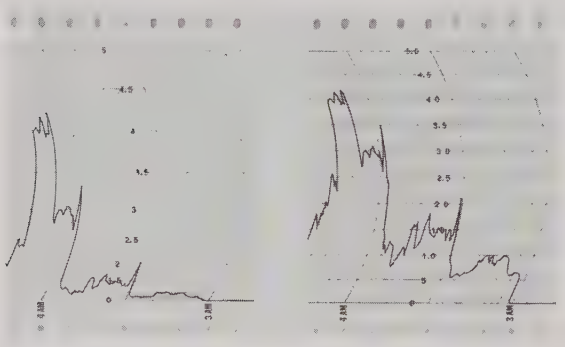


FIG. 4—*Records of the same current made by a multi-purpose recorder and a dynamometer instrument are compared above. Much greater readability in the lower portion of the range is possible with the uniform chart of the multi-purpose instrument (right)*

Continued from page 2

multiplier of 2 or 4 on the 0-300 and 0-600 volt ranges. The 0-100 range numbers apply to all current ranges and the meter can be considered as reading in percent of full scale on any current or millivolt range.

Leads

Calibrated leads are required only with the DC millivolt ranges. Lead length and size are not critical on AC ampere ranges or any voltage ranges. Portable recorders are equipped with two 5-foot leads which are a part of the calibrated circuits only if the recorder has DC millivolt ranges. Instruments with other case styles have screw terminals.

Speed of Response

As with all permanent-magnet, moving-coil instruments, the speed of response is determined by the frame on which the moving coil is wound, and the resistance of the circuit in which the armature coil is connected. Response on different ranges is shown in Fig. 3.

Cases

Portable, wall, flush and front switchboard single cases are available and all except portables are also furnished in twin mounting. Flush cases have 120 volt, 60 cycle fluorescent lighting.

Chart Drives

Briefly, chart drives are divided into three general classes: hand-wound spring, motor-wound spring and synchronous. Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds of ¾, 1½ and 3 inches per second are obtained with external motor attachments.

How to Order—*Specify:*

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall mounting.
2—Chart Drive (Catalog Section 20): Hand-wound Spring, Motor-wound spring, Synchronous. If electric, give voltage and frequency. If electric hour-to-minute shift, give voltage and frequency.
3—Measuring Element: List AC and DC ranges desired. For ease in use, higher ranges should be multiples of lowest ranges.
4—Scale and Chart: Range numbers. Chart speed.
5—Accessories and Attachments (Catalog Section 80): 50 MA Split-core CT, Model D CT, Step-up potential transformer, glass corner in case cover, writing door, carrying case, chart inspector, right- and left-hand chronograph pens (give voltage and frequency).
6—Supplies (Catalog Section 90): Extra charts, pen elements, pen points, ink.

50 MA Split-Core Current Transformer (Below)
Primary Ratings —50, 100, 200 amperes
Secondary —50 MA with short circuiting link
Frequency —50-800 cycles
Window Opening—1 1/16 x 3½ inches
Overall Size —3⅞ x 6¾ x 6⅝ inches high—
—Weight—11 pounds

Step-Up Potential Transformer (Right)
Primary Ratings—5, 15, 30 volts
Secondary—150 volts
Frequency—60 cycles
Overall Size—5 x 6 x 14 inches high—Weight —9½ pounds

THE ESTERLINE-ANGUS COMPANY
Pioneers in the Manufacture of Graphic Instruments
P. O. BOX 596 · INDIANAPOLIS 6, INDIANA

ESTERLINE-ANGUS

OPERATION (EVENT)

Recorders

Instruments to record

When

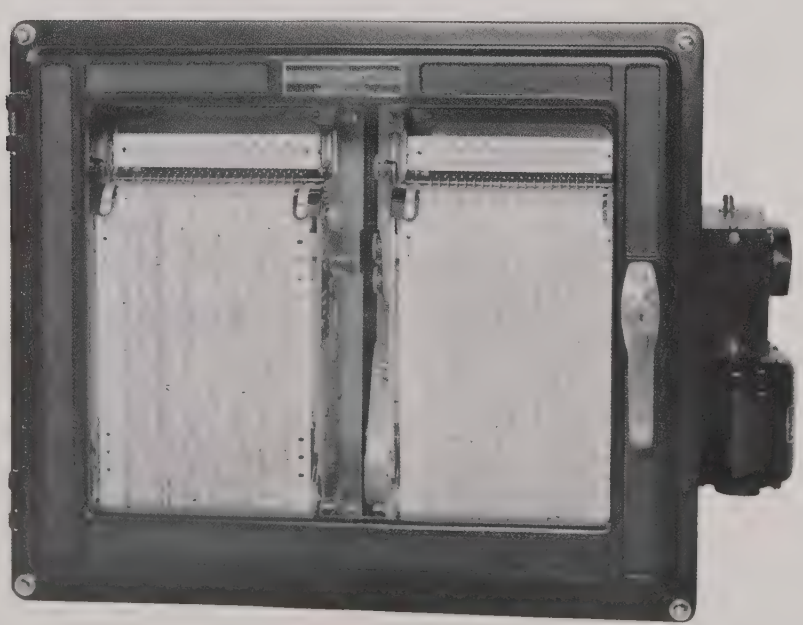
- A machine is productive or idle
- A door is opened
- A bank vault is entered
- A circuit breaker opened or closed

How Long

- A machine is idle
- A power outage lasted
- A rubber or plastic molding cured
- A passenger waited for an elevator

How Many

- Telephone calls are made
- Bottles are filled by an automatic machine
- Articles are made by a screw machine
- Vehicles used a highway



Illustrated are two 20-pen instruments mounted in a twin case. They provide a set of 40 "yes-no" or "on-off" records. The charts have rectilinear coordinates and are synchronized to make easy the comparison of the time of occurrence of the various events. The instrument shown here is further equipped with a high chart speed attachment which provides chart speeds to 6 inches per second.

Catalog Section 50

(MARCH, 1960)

Model AW Operation (Event) Recorders

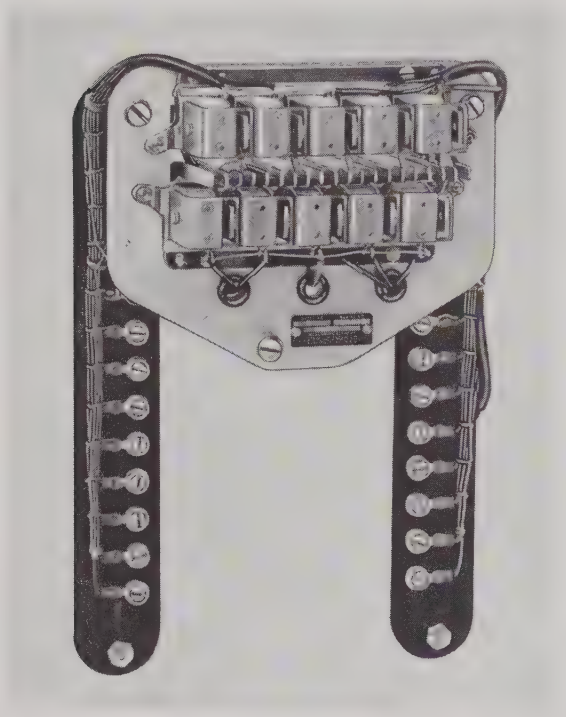


FIG. 2—*The operating element of a 20-pen operation recorder has all 20 electromagnets mounted on a single plate. Completely wired as shown above, it can be installed in and removed from the recorder case without disturbing any internal connections*

THE measuring system or operating element of an operation recorder consists of as many as 20 electromagnets mounted on a single back plate, Fig. 2. Each magnet operates a pen writing on a moving chart. The chart is marked with time of day and is driven by an accurate, rugged chart drive. A large variety of chart drives is available, as described in Catalog Section 20.

When an electromagnet is energized, the corresponding pen moves 1/10 inch off its normal line and stays there until the magnet is de-energized. This lateral deflection of the pen makes it easy for charts to be read. These marks made by each pen show ***when*** something happened, ***how long*** it lasted, and ***how frequently*** the event occurred.

The Pen and Ink Writing System

The ink type writing system is superior to other systems for a number of reasons. If the pen fails to write, it is immediately apparent. The writing system responds immediately to any change in chart speed. The charts required for this system are less expensive, and, because no burning of paper takes place, no ventilation of the instrument is required.

All of the pens are served by a single enclosed inkwell which mechanically supports and aligns the pens. The pen tubes dip into the ink supply through holes in the metal inkwell cover. Short cylindrical counterweights fastened to the pen elements hold the writing pens on the chart paper at all times. These weights project through holes in an extension of the inkwell cover, serving to keep the pen elements in place when the inkwell and pens are removed from the instrument. All of the pens are lifted out of the way when the scaleplate is tilted back to allow for insertion or removal of the chart.

Fig. 4 shows a cross section of the writing system and operating linkage. The inkwell and pen elements appear in Fig. 5.

Types of Recorders

Three types of operation recorders are available:

Voltage type, common return
Voltage type, separate return
Switch type, common return

The type selected depends upon the electrical source and the nature of the application. The following descriptions show the differences between the three types and assist in the selection of the proper one for each application.

Voltage Type

Common Return—The voltage type, common return operation recorder is so named because an external voltage must be available to actuate the electromagnets. The common terminal of the instrument, connected internally to one side of all of the coils, is wired externally to one side of a voltage source (preferably the grounded side). The other terminals of the various coils are wired to the ungrounded terminals of devices on which voltage appears, such as signal lamps, solenoids, or motors. The same voltage which energizes the device being supervised, also actuates the recorder coil connected across the device, as shown in Fig. 19. This type is frequently used to study circuit breaker action, elevator scheduling, timing cycles of automatically controlled processes, and automatic gaging of parts.

FIG. 3—*Four coil assemblies are used: Upper and lower rear, and upper and lower front. Two of these are illustrated above*

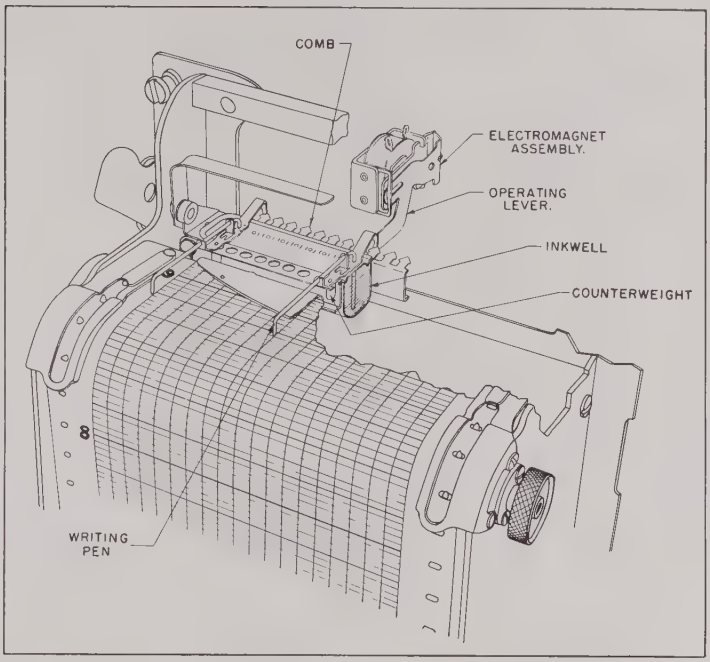


FIG. 4—*Schematic representation of the operating system illustrates the simplicity of the entire mechanism, which contributes to long life and trouble-free service. When the electromagnet is energized, its armature moves and in turn moves the operating lever. Movement of the operating lever is limited by the teeth on the spacer comb. Hence, each pen element moves only this fixed distance in making its record on the moving chart. The limits fixed by the spacer comb teeth also assure that the electromagnet operating levers will engage with tapered slots on the rear of the pen arms when the inkwell-pen element assembly is placed in the recorder*

Heating, refrigerating and air-conditioning systems, as well as a vast range of chemical processes, can be supervised with this instrument by connecting its electromagnets across the terminals of the solenoid valves or dampers used to control the flow of liquids or gases. Similarly, the running and idle time of pumps, fans, blowers, agitators, grinding mills and all other machines which inherently "produce" whenever they run, can be recorded by connecting the instrument coils across the terminals of the motors driving these machines.

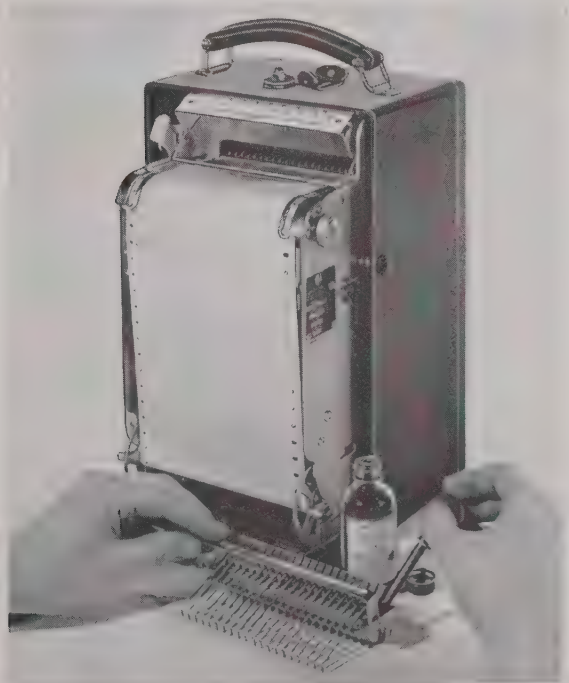


FIG. 5—*All pens are served by a single inkwell which mechanically supports and aligns the pens*

Where the condition to be recorded is mechanical rather than electrical, switches or contactors are used to interrupt an external voltage source and convert the mechanical conditions into electrical impulses which will actuate the recorder. The switch or contactor can be operated from mechanical rotation or thrust, from changing position, or from changes in pressure, temperature or light intensity. Molding time on presses, objects on conveyors, operation of valves, running and idle time of machinery, all may be recorded by this arrangement.

Separate Return—There are applications where the electromagnet circuits must not be interconnected, and for such situations the separate return type of instrument is used. This instrument has a separate pair of terminals for each electromagnet. Typical applications of the separate return type are in load studies in telephone exchanges and in the study of elevator scheduling, where complex systems of wiring and relaying prohibit interconnection between circuits. The use of the separate return on portable instruments eliminates the need for determining polarities and often simplifies installation.

As a safety precaution, the separate return type is often used where connection is made directly across motor terminals. With the common return instrument, one terminal of the motor is always connected through one of the coils in the instrument to the "common" side of the voltage source. Even though

FIG. 6—*Operation recorders can be mounted on the production floor so both operators and supervisory personnel can see the record of productive and idle time*

the motor switch is open, a potential with respect to ground may be present on one of the motor terminals which may constitute a safety hazard. This situation is avoided by the use of the separate return instrument, as illustrated in Fig. 20.

Multiple Voltage Combinations

Voltage type operation recorders can be supplied with several groups of coils wound for different voltages. Multiple voltage combinations are often used in elevator traffic surveys, where different banks of elevators use different signaling voltages, and in plant production checks, where various machines may operate on different potentials. Recorders used in electric generating stations and substations, where two different station battery voltages are present, are furnished with two groups of coils of different ratings and with separate returns as well, to prevent interconnection of existing control circuits.

Recorders with each pen circuit having two or more voltage ratings can also be furnished. The instrument is usually self-contained for the lowest voltage with external circuit resistors for higher voltages. This feature is useful in plant surveys where several voltages exist, and in signaling circuits where more than one potential is encountered.

Switch Type

Where the operation recorder is to be actuated solely by switches or contactors, and where the power supply is AC, the switch type instrument is recommended. This instrument derives its name from the fact that it is restricted to use with switches or contactors. There must be no existing voltage in the circuits to which the recorder electromagnets will be connected.

A small step-down transformer, mounted inside the case, supplies approximately 24 volts AC to actuate the electromagnets. One side of the transformer secondary is connected to one side of all the coils inside the instrument, and the other side of the secondary is brought out to a common terminal on the case. See Fig. 21. The transformer can be furnished with its primary wound for 120 or 240 volts, 50-60 cycles.

Applications of the switch type instrument are the recording of opening or closing of doors, the produc-

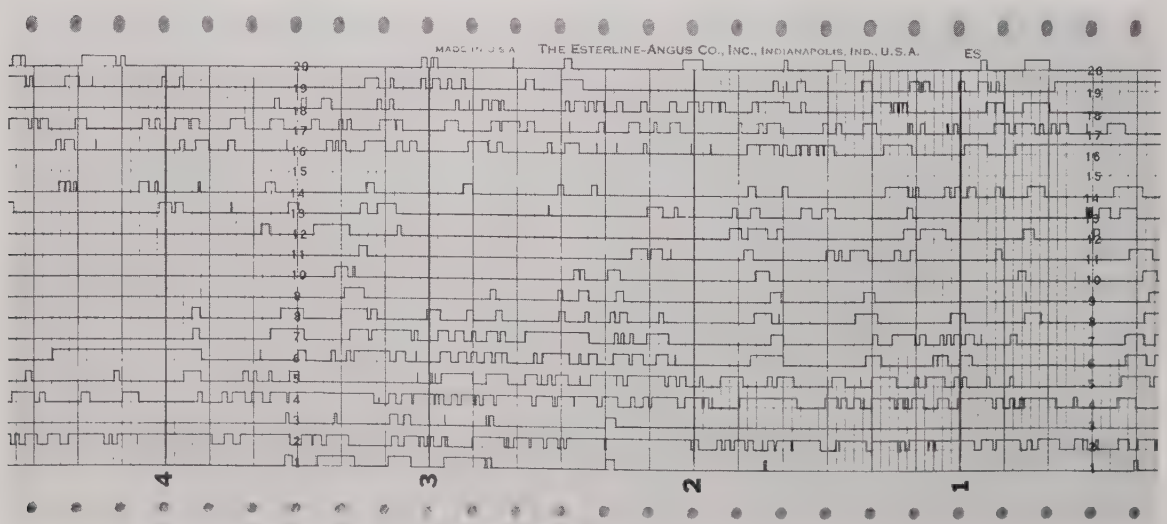


FIG. 7—*Expansion of a plant operating its own dial telephone system made it necessary to add more lines. A 20-pen operation recorder was installed to determine loading on the existing lines. The study continued for several weeks, monitoring 20 lines at a time for a 24-hour day. This typical section of chart shows that line No. 3 had only 8 short calls, while line No. 2 had 59, some of which were quite long. After the study, phones were regrouped so that all lines were more equally loaded. The anticipated number of new lines was reduced*

tive and idle time of screw machines and presses, the passage of objects on a conveyor, the flow of liquid in pipes, and the revolutions of a shaft.

Choice of Types

The selection of the type of instrument depends upon the source of supply of the voltage to operate the electromagnets, and upon the means employed to produce the impulses. The type will depend upon whether the source is AC or DC, and whether or not all pens are to be operated from the same source.

Either the switch type or voltage type of recorder can be used where switches, contacts or relays operate the electromagnets, and where the source is AC. The use of the switch type, however, permits low operating voltages which make possible a reduction in wiring costs, and also eliminates the hazards of higher voltages.

When only DC is available, the voltage type must be used. If the impulses are to be obtained from a switch action, the common return type may be employed. This type may also be connected across voltage-operated devices where a common return is permissible. The voltage type with separate return must be utilized in conjunction with voltage-operated devices where a common return is not permissible. It is also used on complicated relaying systems, or on motors where safety considerations prohibit interconnection.

Total Number of Pens

In deciding on the total number of pens required, thought should be given to possible future growth. After the instrument is in service, it is often desired to monitor some additional machines or processes, once the value of these records is apparent. Adding electromagnets must be done at the factory and it is more expensive than including extra capacity when the instrument is built. Taking the recorder out of service and losing valuable records can be avoided by ordering more pens initially.

Where it appears that 6 pens are needed at the time of the initial installation, at least 10 electromagnets should be put in the recorder. Similarly, where 14 or 15 pens are needed, order 20. The writing pens can be left out of the recorder until the corresponding operating coils are put in service.

Methods of Actuating

The simplest method of actuating the electromagnets of the operation recorder is by the direct application of voltage. Signal voltages on elevator systems, voltages across motor terminals, voltages across indicating lamps on circuit breaker systems, voltages across coils of solenoid valves and relays, voltages on railroad interlockers, are all applied directly to the instrument coils without the use of any auxiliary apparatus.

There are some applications where the voltage varies over too wide a range for satisfactory operation of the instrument or where currents are too large to be brought to the instrument. In such instances, appropriate relays should be connected into the circuits to provide the necessary "on-off" impulses. For example, in arc welding, currents of several hundred amperes are encountered, requiring special current relays to operate the recorder. Also, in arc welding, the no-load voltage is several times the working voltage, requiring relays which will respond to the arc voltage without being damaged by the open circuit voltage. See Fig. 17. On some machinery, such as grinders, punch presses and heavy planers, large variations of current occur between no load and full load.

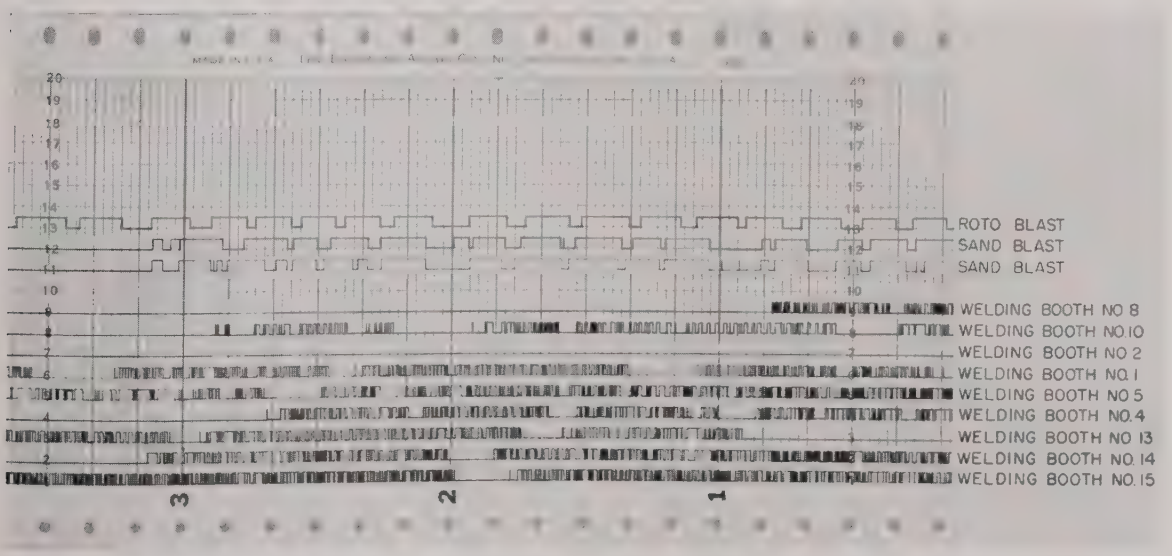


FIG. 8—*Pens 1-9 show the operation of welders in a steel fabricating plant. Pens 11, 12 and 13 show the active and idle time of casting cleaning machines. To provide for the future addition of more production equipment, coils 14-20 are in the instrument but these 7 pen elements will not be used until they are needed. Thus 7 more pieces of equipment can be added to the record at any time*

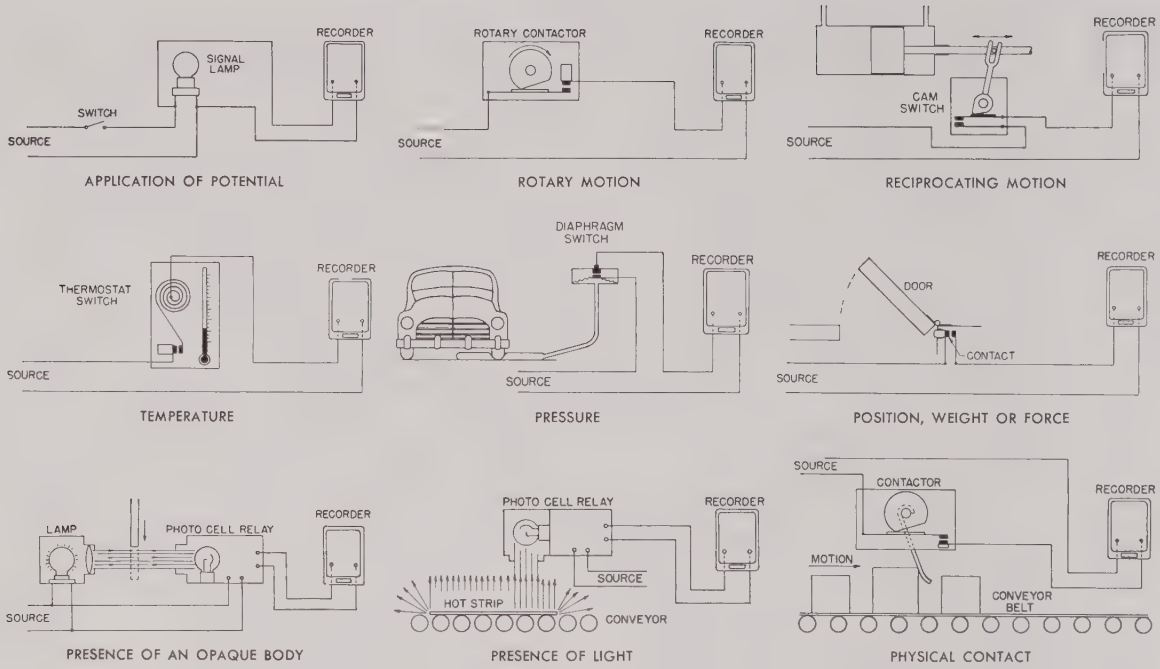


FIG. 9—*These sketches show a few of the variety of ways in which the pens of an operation recorder may be actuated*

Current relays may be installed on these machines to close near full load current and thus cause the instrument to record only the productive time.

The majority of phenomena to be studied are mechanical rather than electrical, and switches or contactors of some sort must be used to convert these phenomena into electrical impulses. In recording the operation of hydraulic presses in plastic molding, rubber vulcanizing, or vegetable oil pressing, a mechanically operated switch is mounted so as to be actuated when the press closes. A similar arrangement is used to record the opening and closing of doors on elevators, bank vaults, cold rooms and mine shafts; to record the position of valves, dampers and gates; and to record the movement and spacing of streetcars, subway trains and trolley buses.

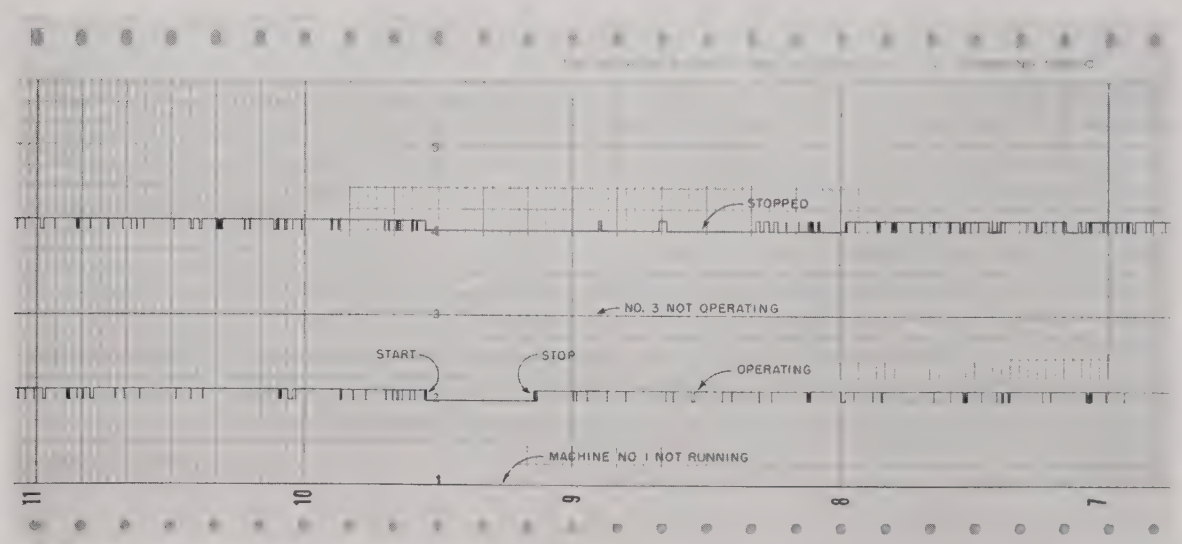


FIG. 10—*This operation recorder chart was made in a bottling plant with two of the four machines running. Frequent stops of short duration and several shut-downs of 10 to 20 minutes can be seen. Installation of the recorder resulted in substantial reduction of lost time*

*Switches and Contactors**

Suitable switches, intended for actuation by physical movement, may be obtained from the Micro-Switch Div., Minneapolis-Honeywell Regulator Co., Freeport, Ill.; Production Instrument Co., Chicago; Veeder-Root, Inc., Hartford, Conn.; and Mu-Switch Div. Acro Mfg. Co., Columbus, Ohio. Limit switches are available from Cutler-Hammer, Inc., Milwaukee; General Electric Co., and Westinghouse Electric Corp.

Heavy duty rotary cam switches, made by Veeder-Root, Inc., are designed for direct connection to rotating shafts. Each rotation of the shaft produces one electrical impulse. This same switch, fitted with a projecting lever arm, may be connected to reciprocating machinery.

Switches with extended levers may be used to count passage of objects on a conveyor and in some cases to record movement of billets, castings and tools to and from heating furnaces. These switches are mounted so that the extended lever will be actuated by the passing objects. The Production Instrument Co., Chicago, supplies this type of switch.

There are many counting applications where a mechanical device is not satisfactory. Objects may be too irregular in shape to insure moving a switch lever, they may be inaccessible, as in a chute, or they may be too delicate to move a lever, as in the case of cloth or paper. By placing a light source and an electric eye on opposite sides of the conveyor belt and just above the surface, all objects regardless of shape or size, will interrupt the beam and be counted. A few of the companies making photoelectric relays are: General Electric Co.; Photoswitch Div., Electronic Corp. of America, Cambridge, Mass.; The Ripley Co., Middletown, Conn.; Westinghouse Electric Corp., and Weston Electrical Instrument Corp., Newark, N. J.

*The list of manufacturers in the following paragraphs is not intended to be complete. Only a few are mentioned to be of assistance in applying operation recorders.

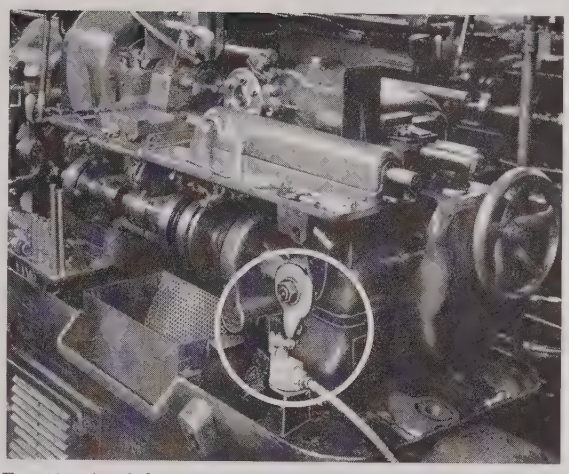


FIG. 12—*A switch operated by the over-arm cam of a screw machine will actuate its pen on the operation recorder only when work is being done*

Since the photo-electric cell responds to the presence of light, it may be used to indicate the opening of furnace doors, movement of glowing billets, presence of flame in a furnace, or light in a room. The "Vis-a-Flame" tube, made by Minneapolis-Honeywell Regulator Company, is responsive to radiant heat and may be used to record movement of hot castings, billets, furnace doors, glass pots, etc.

Switches are available which will close electrical contacts when a desired pressure or vacuum exists. Pressure-operated switches may be connected to presses to indicate their production, to water mains to indicate pressure, or to tanks to show filling and

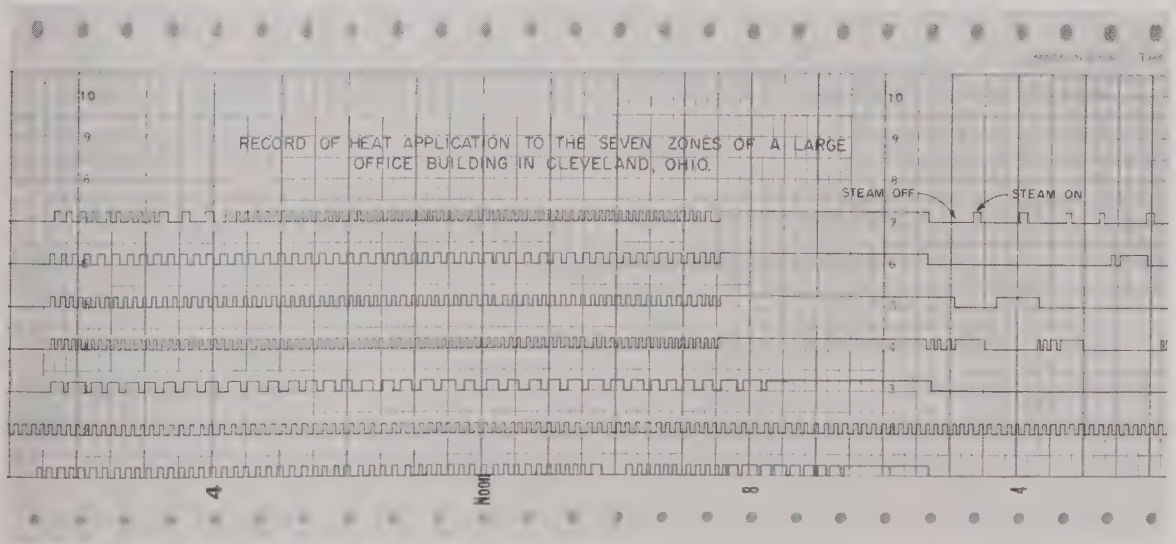


FIG. 11—*The action record of seven valves controlling the heating in different zones of a large Cleveland office building is shown in this record. Note that zone 2 was heated continuously but the other 6 zones were heated only during working hours. Service personnel will follow instructions when their actions are recorded*

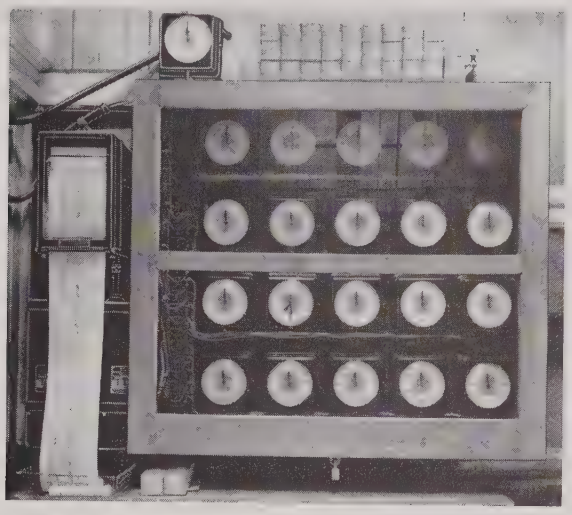


FIG. 13—*While the operation recorder shows productive and idle time of a group of arc welders, 20 clocks totalize the actual welding time for each operator*

emptying. Pressure and vacuum switches are particularly applicable to recording the operation of heating, refrigeration, and air-conditioning systems. The Minneapolis-Honeywell Regulator Co., Mercoid Corp., Chicago, Cook Electric Co., Chicago, and Barksdale Valves, Los Angeles, Calif., manufacture such switches.

The Mercoid Corp. also makes a float-operated switch for recording liquid levels. The Autocall Co., Shelby, Ohio, manufactures a flow indicator which closes its contacts when there is a flow of liquid through a pipe, as in automatic sprinkler systems. Thermostats and thermal relays, to indicate when certain temperatures are attained in liquids or in free space, are made by Fenwal, Inc., Ashland, Mass.; Thomas A. Edison, Inc., West Orange, N. J.; and Minneapolis-Honeywell Regulator Co.

Avoiding Misleading Records

In all applications of the operation recorder, it is essential that the instrument respond only when the desired action, usually actual production, takes place. This may involve the fulfilling of two or more conditions simultaneously. In such cases, two or more switches are used in series, the pen-actuating electromagnet being energized only when both switches are closed. For instance, a screw machine may continue its cycle of operations although it has run out of stock. To eliminate false recording, two contactors are used in series. One is connected to the cam shaft, while the other is mounted so as to be closed by the piece of stock being machined.

On textile looms, on rotary presses in newspaper plants, or on cable machines, many shafts will be rotating even when there is no production. To prevent false records, cam switches may be attached to idler rolls, so that the impulses will be sent to the recorder only when stock is actually moving through the machine or press, causing the idler to rotate.

In arc welding, useful deposition of metal takes place only when there is current flowing and when, at the same time, there is voltage across the arc. If the arc is broken while the welding generator is running, there will be voltage, but no current. If the electrode is short-circuited against the work, there will be current, but no voltage. To insure that the

Rectangular Pattern

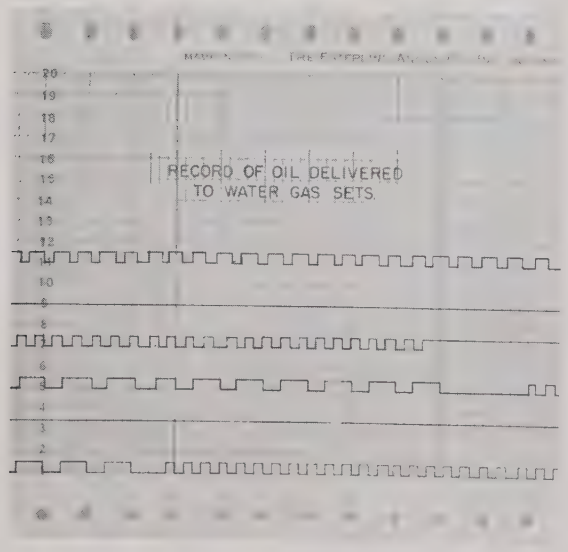


FIG. 14—*By placing contacts on the dials of oil meters, an operation recorder shows the rate at which oil is delivered to 6 water gas sets*

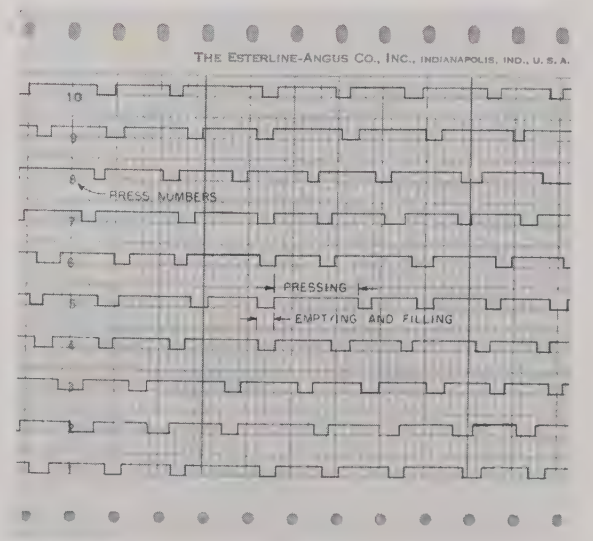


FIG. 15—*This record shows the operation of 10 cotton-seed oil presses. The recorder pens are energized by a pressure switch on each press*

Band Pattern

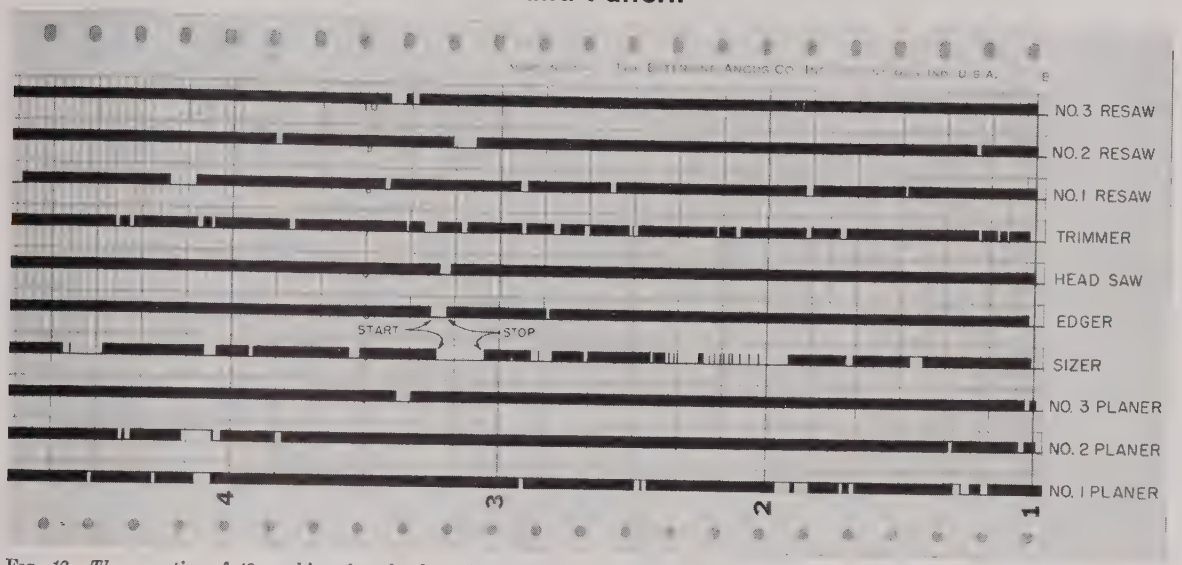


FIG. *16—The operation of 10 machines in a lumber mill is shown above. The relatively few idle periods are the result of considerable effort on the part of the superintendent and operating people. Such good records can be obtained only by having the operators write down the reason for each delay. Then it is up to management to remove or minimize those causes*

instrument is energized only during useful welding, two relays are used, one responsive to arc current, and the other responsive to arc voltage. The contacts of the two relays are wired in series, so the pen electromagnet is energized only when both relays are simultaneously closed as shown in Fig. 17. Relays of this type are manufactured by Automatic Electric Manufacturing Co., Mankato, Minn.

Counting and Totalizing

In many installations of the operation recorder, it is desirable to add up total time. For example, on an electric arc welding circuit it is advantageous to know for each working day how many hours of actual welding have been accomplished. By connecting a self-starting synchronous clock in parallel with each electromagnet of the voltage type operation recorder, the clock will run only when the electromagnet is energized, and will thus totalize the useful welding time. See Fig. 13. Time totalizers or hour counters, fitted with direct reading dials, are supplied by the General Electric Co.; Sangamo Electric Co., Springfield, Ill.; Weston Electrical Instrument Corp.; and Westinghouse Electric Corp.

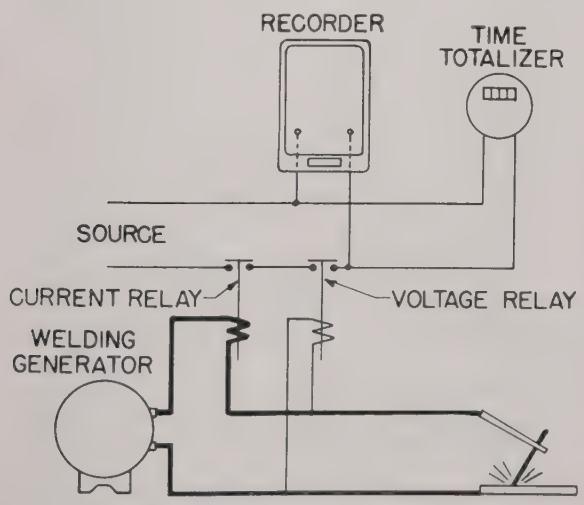


FIG. 17—*Use of both current and voltage relays to energize a pen circuit insures operation of the pen only when welding is actually being done*

Frequently it is valuable to know the total number of operations within a given time. Such totals can be obtained by connecting a counter in parallel with each electromagnet of the voltage type recorder. Counters of this type are made by Veeder-Root, Inc. and Production Instrument Co.

Hour counters and totalizers can be used only with the voltage type instrument, since the internal transformer in the switch types does not have enough capacity to operate external devices.

Types of Records

Three different types of record patterns may be obtained on the chart, depending upon the relation of the length of time the pen is energized, the time the pen is de-energized, and the chart speed. These types are the rectangle, band, and impulse patterns, so-called because of their appearance on the chart.

Rectangle Pattern—This is the most common type of record. The electromagnet is energized only when some event or condition occurs, the time of energizing being long enough for the pen to produce an open rectangle on the chart. When the condition does not

Impulse Pattern

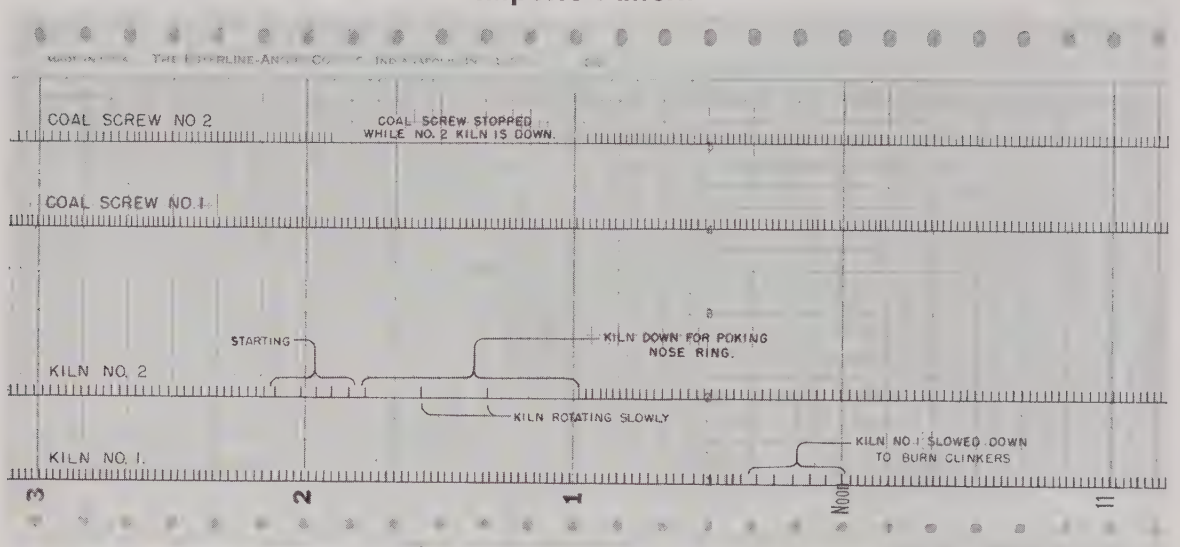


FIG. 18—*This record shows 4 pens being used to chart operation of 2 cement kilns, and the coal screws feeding them. Movements of the coal screw pens indicate every hundredth revolution. Pens on the kilns show each revolution. The chart shows that Kiln No. 2 was slowed down at 1 P.M. to poke a nose ring. It continued revolving one revolution every twenty minutes to prevent warping. Coal screw No. 2 stopped entirely while its corresponding kiln was down. The chart also shows that Kiln No. 1 was slowed down at noon, in this case to burn clinkers. In order to gain more efficiency from a cement kiln, the stops are observed by the superintendent and the causes analyzed*

exist, the electromagnet is de-energized. Although the chart speed is not critical, speeds should be used which are no higher than necessary to obtain the required accuracy in time measurement. Typical records of this type are illustrated in Figs. 14 and 15.

When pressure is applied to a curing press, Fig. 15, the corresponding recorder pen is energized by the contacts of a pressure-operated switch in the hydraulic line. The pen remains in the "on" position as long as the pressure is maintained. Each rectangle shows the duration of one operation. Other applications which produce the rectangle pattern are the recording of the passage of trains through railroad interlockers, checking circuit breaker operation, studying elevator movements, and supervising many chemical processes.

Band Pattern—The band type record is produced when an operation recorder pen is actuated by a rapidly closing and opening contactor. This contactor is usually one which is connected to reciprocating or rotating machinery so as to open and close with each stroke or revolution. Chart speed and method of actuation are chosen so that the cycle occurs with enough rapidity in comparison to the chart travel to cause the pen to produce overlapping marks. The resulting bold band, produced during machine activity, contrasts sharply with the single line drawn when the machine is not running. Fig. 16 shows a band record of productive time on ten machines in a lumber mill. This style of record is also obtained when the operation recorder checks the working and idle time of automatic screw machines making small parts, cable braiding machines, etc. There should be not less than 80 strokes and not more than 200 strokes of the pen per inch of chart travel in the band pattern.

Impulse Pattern—This type of record is produced when the pen is energized only momentarily. The return stroke of the pen falls on practically the same path as the active stroke, so that the pen draws a single crosswise mark. As the chart moves ahead, other marks, with spacing in between, are produced by similar actions. The number of these marks per given time, and the spacing between them, may be accurately determined. Fig. 18 is an example of this type of presentation, showing revolution counting of

Continued on page 12

TABLE I—STANDARD CHART SPEEDS, TIME VALUES AND RUNNING TIMES

Chart Speed	Spacing of Minor Divisions	Time Value per Minor Division	Time One Chart Will Last
3/4 inches per hour	1/8 inch	10 minutes	65-2/3 days
1-1/2inches per hour	1/8 inch	5 minutes	32-1/3 days
3 inches per hour	1/10 inch	2 minutes	15-2/3 days
6 inches per hour	1/10 inch	1 minute	7-1/3 days
12 inches per hour	1/10 inch	1/2 minute	3-2/3 days
3/4 inches per minute	1/8 inch	10 seconds	26-2/3 hours
1-1/2 inches per minute	1/8 inch	5 seconds	13-1/3 hours
3 inches per minute	1/10 inch	2 seconds	6-2/3 hours
6 inches per minute	1/10 inch	1 second	3-1/3 hours
12 inches per minute	1/10 inch	1/2 second	1-2/3 hours
3/4 inches per second	1/8 inch	1/6 second	26-2/3 minutes
1-1/2 inches per second	1/8 inch	1/12 second	13-1/3 minutes
3 inches per second	1/10 inch	1/30 second	6-2/3 minutes

NOTE: Special change gears are available for chart speeds of one inch per minute and per second. When using these speeds and a chart with 1/10 inch spacing of the minor divisions, each minor division equals 1/10 minute or 1/10 second, respectively. Such speeds are useful in time studies.

Model AW Operation (Event) Recorders

All recorders are guaranteed to operate at voltages 15% above or below rating

VOLTAGE TYPE—Specify Common or Separate Return

Rated Voltage	Coil Style	Milli-amperes	Watts per Circuit	Ohms per Coil (DC)	Ohms in Series With Coil
Direct Current*					
2 Volts	N	570	1.1	3.5	None
4 Volts	K	286	1.1	14	None
6 Volts	J	231	1.4	26	None
8 Volts	G	131	1.0	61	None
10 Volts	F	99	1.0	101	None
12 Volts	F	119	1.4	101	None
14 Volts	E	90	1.3	156	None
16 Volts	D	67	1.1	238	None
18 Volts	D	76	1.4	238	None
24 Volts	C	65	1.6	372	None
28 Volts	B	42	1.2	666	None
32 Volts	A	29	0.9	1092	None
48 Volts	T	29	1.4	1650	None
125 Volts	B	41	5.2	666	2400
250 Volts	T	26	6.5	1650	8000
50-60 Cycles AC					
6 Volts	N	447	1.6	3.5	None
12 Volts	K	233	1.7	14	None
24 Volts	G	103	1.5	61	None
120 Volts	T	20	1.5	1650	None
240 Volts	T	21	4.5	1650	7000

SWITCH TYPE, Common Return Only

50-60 Cycles AC		Electrical characteristics of individual coils are same as listed for voltage type, 24 volt, 50-60 cycle, style G coil, in above table.
120 Volts	G	
240 Volts	G	

*In permanent installations, it is preferable for the recorder coils to be connected to the negative polarity of the power supply, the switches or relay contacts to be in the positive lead between the power supply and the recorder.

Charts—Rectilinear. 1700 series. See Catalog Section 90.
Use chart 1705 for recorder with 1 to 5 pens.
Use chart 1710 for recorder with 6 to 10 pens.
Use chart 1720 for recorder with 11 to 20 pens.
Use chart 1740 for right-hand side of twin recorder having 20 pens in the left-hand side.

Scales—To match number of pens.

Leads—None furnished. Leads used with switch type recorder may have resistance up to 35 ohms per circuit (approximately 5000 feet of No. 18 wire, 2500 feet one way).

Binding Posts—Not furnished. Connections are made with machine screw terminals.

Multipliers—None required for recorders rated 120 volts AC, 50-60 cycles and 48 volts DC. Higher voltage recorders may use one or two multipliers, depending on rating and number of pens.

Response Speed—For pens to make full deflection, circuit must be closed or open for at least 1/20 second, allowing a maximum of 10 on-off cycles per second with equal "on" and "off" periods.

Chart Speed—Charts should be run fast enough to give the desired timing accuracy, yet not so fast as to cause excessive paper consumption and laborious inspection. To count the individual strokes of each pen, the chart speed should be selected so that there are not more than 30 strokes per inch of chart travel. When using the band type record, speed should be such that there are not less than 80 strokes nor more than about 200 strokes per inch of chart travel. (See Table I, page 10.)

Pen Location—Pens will be located in standard positions designated on charts 1705, 1710 and 1720, unless otherwise specified.

Future Pens—See page 5.

Dielectric Test—1500 volts, 60 cycles, for one minute.

Intermediate and Special Ratings—Voltage type recorders can be furnished for any voltage from 2 to 250 volts DC and 6 to 240 volts AC, 50-60 cycles. For series operation, such as in the secondary of a current transformer, special low impedance coils should be used. Consult factory, giving details of application. Switch type recorders are available only in the ratings shown in the table.

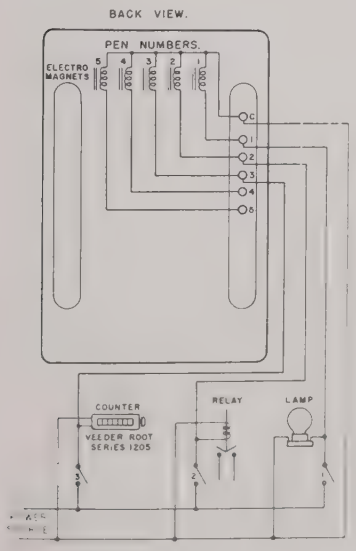


FIG. 19—*Wiring diagram of voltage type, common return recorder actuated by line voltage across signal lamps, relays or counters*

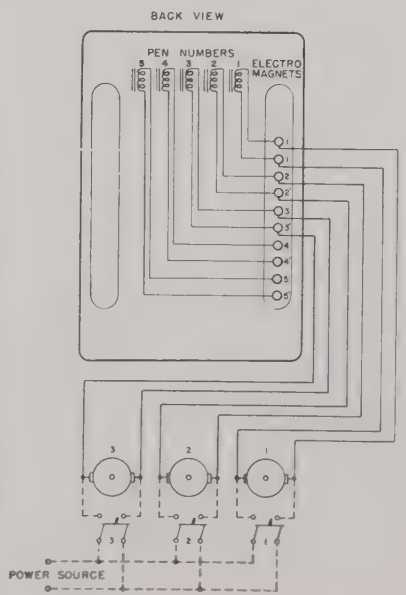


FIG. 20—*Wiring diagram of voltage type, separate return recorder. Separate return circuits are available only on voltage type recorders*

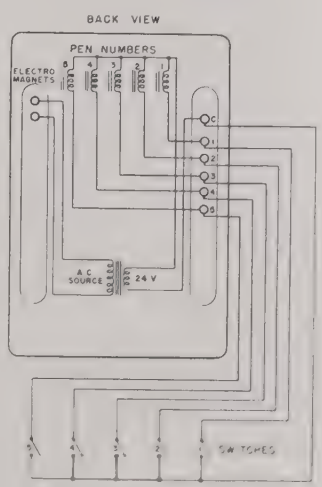


FIG. 21—*Wiring diagram of switch type operation recorder. This instrument is furnished only with common return pen circuits*

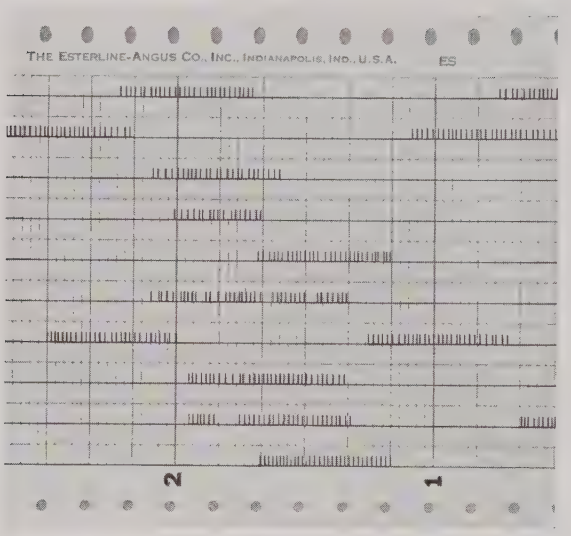


FIG. 22—*Each mark of a pen shows the withdrawal of a billet from one of 10 heating furnaces. Heating time and rate of withdrawal can be taken from the record*

Continued from page 10

slow moving devices. When it is desired to count individual operations, there should be not more than 30 strokes of the pen per inch of chart.

The impulse record is also obtained when counting objects on a conveyor belt, billets from a heating furnace, or vehicles on a highway. This type of pattern usually results when the recorder is used to gather time study data. The observer is supplied with several push buttons which actuate various pens of the recorder. When a machine operator or an assembler performs a certain operation, the observer presses the proper button, thus producing a mark on the chart. Time studies are then made from the record thus produced.

Combination Pattern—It is sometimes desired to make one pen produce more than one type of record to indicate different conditions. For example, operation recorder pens showing train operation in Chicago's subway system, indicate when a signal to start has been given. This is the start of the rectangle pattern. The end is when the train actually starts. When the length of this pattern exceeds a predetermined time, the pen is caused to vibrate and paint a band. Hence, overtime standing in any station is apparent at a glance.

Similarly, an elevator causes the pen to draw a rectangular pattern. A rectangle is drawn while the elevator is standing at the top as well as at the main floor. To distinguish between the two, the pen circuit can be interrupted to paint a band while the elevator is standing at the top floor. Then, direction of travel is always obvious by simply noting what type of pattern started the portion of record being examined.

Cases

Portable, wall, flush and front switchboard single cases are available and all but portable are also furnished in twin mounting. Flush cases have 120 volt, 60 cycle, fluorescent lighting. For certain other power sources, incandescent lighting can be furnished.

Chart Drives

Briefly, chart drives are divided into three general classes: hand-wound spring, motor-wound spring and synchronous. Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds of ¾, 1½ and 3 inches per second are obtained with external motor attachments.

How to Order—*Specify*

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall Mounting.

2—Chart Drive (Catalog Section 20): Hand-wound Spring, Motor-wound Spring, Synchronous. If electric give voltage and frequency. If electric hour-to-minute shift desired, give voltage and frequency.

3—Operating Element: Voltage type, common return; Voltage type, separate return; Switch Type. Voltage, Frequency, Number of Electromagnets, Number of pens.

4—Chart (Catalog Section 90): Chart number, Chart speed.

5—Accessories and Attachments (Catalog Section 80): Writing door, glass corner in case cover, chart inspector, carrying case, electric counters.

6—Supplies (Catalog Section 90): Charts, extra pen elements, pen point cleaners, ink.

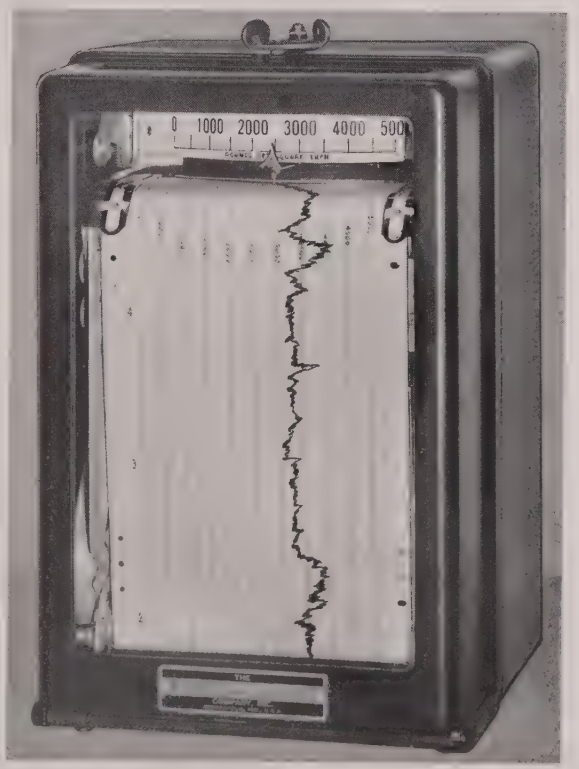
THE ESTERLINE-ANGUS COMPANY
Pioneers in the Manufacture of Graphic Instruments
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

Catalog Section 50
Printed in U.S.A., 15M

Product Representatives
in Most Principal Cities

ESTERLINE-ANGUS
Pressure and Vacuum
Recorders

Bourdon Tube
and Bellows Types

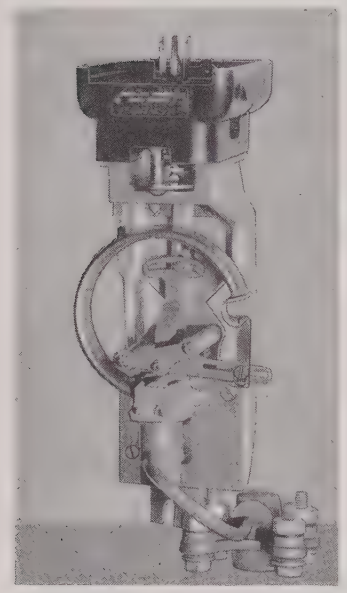


Pressure and vacuum records are essential guides in the operation of countless processes, in the operation and maintenance of many types of machines and in conducting a wide variety of industrial tests and in research. Because of their rugged design, low maintenance, and large selection of chart speeds, E-A strip-chart pressure and vacuum recorders are specified by those who place a premium on trouble-free performance.

Liquid level recording, water pressure testing of oil-well drill pipe, hammer in hydraulic systems, and the operation of brake and tire testing machines and hydraulic draw benches are a few of the many interesting applications of these rugged recorders.

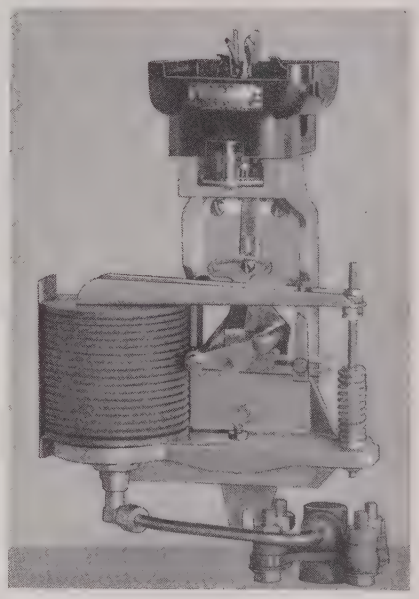
Catalog Section 60
(January 1957)

Model AW Pressure and Vacuum Recorders... for the Tougher Operating Requirements



← Fig. 1—*The Bourdon tube pressure measuring element is used in both recorders and contact-making instruments in the ranges between 0-25 and 0-6000 PSI and for 30-0-30 Inches of Mercury, vacuum-pressure*

Fig. 2—*The bellows pressure measuring element is used in both recorders and contact-making instruments in the ranges between 0-1 and 0-15 PSI pressure and also for 0-30 Inches of Mercury vacuum* →



TWO STYLES of measuring elements, illustrated in Figs. 1 and 2, are required to cover the ranges from 0-30 Inches of Mercury vacuum to 0-6000 PSI pressure. Both measuring elements are simple, compact and practically free from maintenance. They are intended for use on water, steam, air or oil pressures or any fluid not corrosive to copper, brass or alloy steel.

Pressure and vacuum recorders are quite often assembled together in twin cases where it is desired to have both pressure and vacuum records of a system in time synchronism. A pressure recorder and a position recorder are also frequently twin mounted to synchronize the records of working pressure and ram motion on a molding press or of platen movement and pressure in flash welders.

Scales and Charts

Pressure and vacuum recorders have scales uniformly divided along the pen arc (4300 series). The pressure range should be selected so that the normal maximum pressure is not more than ⅔ of full scale and the maximum possible pressure does not exceed full scale. The pressure ranges listed on page 3 are the standard ranges of bellows and Bourdon tubes, but some intermediate calibrations can be furnished.

These recorders are usually scaled in terms of applied pressure. However, it is possible to scale them in terms of total pressure on a press platen, force, torque, or any quantity bearing a direct relation to pounds per square inch. A number of offset zero vacuum-pressure ranges are available, such as 15-0-135 PSI. Special charts must be provided for such ranges or charts without range numbers used.

Zero

A zero adjusting lever in the bottom of the case enables the user to return the instrument to zero, if required. The zero adjustment should be made when there is no pressure in the system or with the piping disconnected at the recorder.

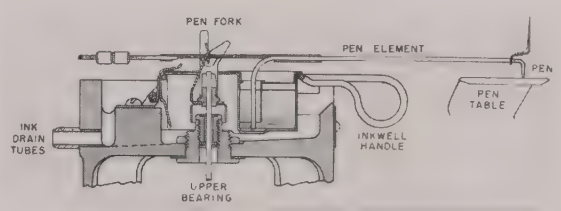


Fig. 3—*Cross sectioned view shows the top of the measuring element, with inkwell and pen element in place, drain tubes that prevent spilled ink from traveling down the staff, as well as the canopy protecting the top bearing*

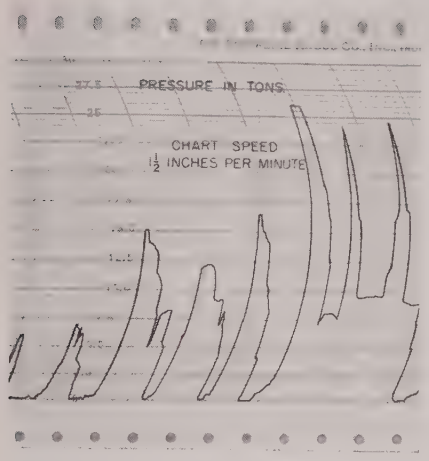


FIG. 4—*This section of chart shows the record of pressure required to press shafts in electric motor rotors. The instrument is scaled in terms of total pressure on the ram. Pressing of three different sizes of shafts and rotors is shown in the record. Variations in the pressure required for a given shaft size indicate differences in shaft or hole sizes and must not exceed predetermined limits for each shaft size*

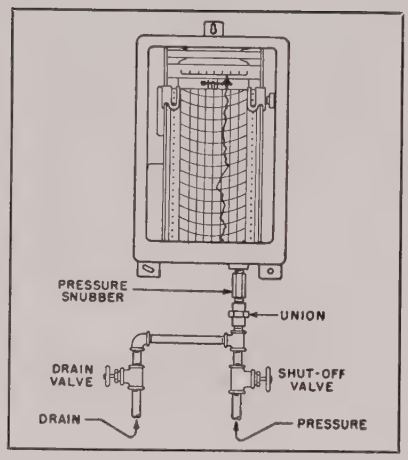


FIG. 5—*Suggested method of installation. A pressure snubber or needle valve should be used, to prevent painting the chart, if appreciable pressure changes occur in less than about ⅛ second. Use of both the shut-off valve and a drain valve makes it easy to release pressure and check the zero setting when desired. The pipe connection is brought out the bottom of wall (illustrated) and flush switchboard cases and out the rear of portable and front switchboard recorders*

Pressure and Vacuum Ranges Available

Pounds Per Square Inch	Type of Element
(Pressure)	
0-1	Bellows
0-2	Bellows
0-5	Bellows
0-10	Bellows
0-15	Bellows
0-30	Bourdon
0-60	Bourdon
0-100	Bourdon
0-160	Bourdon
0-200	Bourdon
0-300	Bourdon
0-400	Bourdon
0-500	Bourdon
0-600	Bourdon
0-800	Bourdon
0-1000	Bourdon
0-1600	Bourdon
0-2000	Bourdon
0-3000	Bourdon
0-4000	Bourdon
0-5000	Bourdon
0-6000	Bourdon
(Vacuum) 0-30 Inches of Mercury	Bellows
(Vacuum-Pressure) 30-0-30 Inches of Mercury	Bourdon

Response Speed

Pressure and vacuum recorders have considerable torque and, therefore, a high speed of response. The time required for the pen to complete a swing one way is approximately ⅒ second. However, to avoid inking difficulties, a pressure snubber or needle valve should be used to reduce the speed of response, if appreciable changes in pressure occur in less than about ⅛ second. The opening or closing of valves, and the pressure on slow reciprocating pumps are examples of pulses that may need to be damped out, to prevent painting a band on the chart.

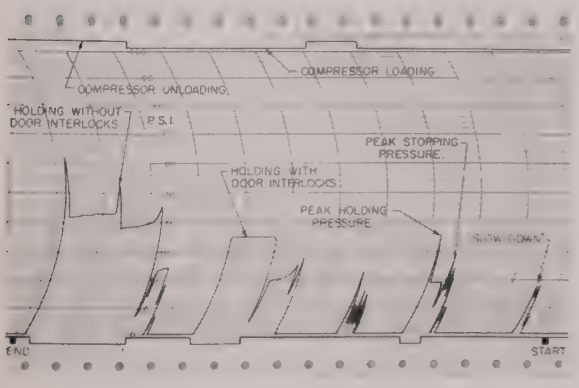


FIG. 6—*The pressure recorder producing this record was used on a bus and the record shows handling of the air brakes. The instrument was equipped with two chronograph pens, one used to indicate stops and the other to show operation of the air compressor*

Charts—Uniformly divided, 4300 series, refer to chart list 355 or catalog section 90.

Scales—To match 4300 series charts. Normally calibrated to read direct in pounds per square inch. Can be scaled feet of water, total tons of force, mm. of Hg, etc. If such scale requires an unlisted PSI calibration, see Special Ranges, below. Scale should be selected so normal pressures are below ⅚ scale and maximum pressure does not exceed full scale.

Zero—Left-hand zero, except center-zero vacuum-pressure recorder. The zero can be shifted only a few percent with the zero adjustor.

Special Ranges—Bellows—Any intermediate range. Bourdon Tube—Consult factory if odd range differs more than 5% from a listed range. Offset zero vacuum-pressure recorders available at additional cost.

Response Speed—Time required for pen to complete swing one way is approximately ⅒ second. To avoid painting the chart, a pressure snubber must be used if appreciable changes in pressure occur in less than about ⅓ second.

Guaranteed Accuracy—2% of full scale pressure or vacuum.

Pipe Connections—¼ inch female connections on bottom of flush and wall types; back of portable and front switchboard types.

Bleed Screw—Furnished on bellows type recorders to be operated by liquids. Bleed screw can be supplied on Bourdon tube meters, with ranges below 0-800 PSI, to release all air except that in the tube itself.

Pressure Snubber—Ashcroft No. 1106 snubber, with ¼ inch nipple, suitable for pressures up to 5000 PSI, should be used wherever it is desirable to damp out fluctuations which cause vibration of the pen or painting of the chart.

Bourdon Tube Recorders

In the Bourdon tube measuring element, Fig. 1, one end of the tube can move when pressure is applied. This motion, through a linkage and rack and pinion, is transmitted to the pen staff. A small bronze spring on the pen staff absorbs any back-lash in the movement.

Bronze tubes are used for ranges up to 0-1000 PSI and alloy steel tubes for higher pressures. The volume of the Bourdon tube system is about 1.25 cu. in. Normally, no bleed screw is furnished on Bourdon tube pressure recorders because it is usually unnecessary to bleed the system. In those cases where it must be done, a screw can be supplied at the fixed end of the Bourdon tube, to bleed all of the air in the system except that in the tube itself. Steam should not be permitted in the Bourdon tube. Where steam pressure is to be recorded, a water loop should be installed adjacent to the recorder.

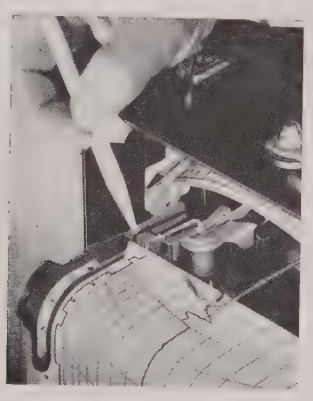


FIG. 7—*Chronograph pens can be mounted in either or both margins of the chart as illustrated. Pens are available for operation on 2-250 volts DC, 6-240 volts, 25, 50 or 60 cycles AC*

Bellows Recorders

The actuating unit in Fig. 2, is a one-piece cylindrical metal bellows, made of brass. One side of the bellows is restrained and the other side is permitted to move in opposition to a coiled spring when pressure or vacuum is applied. Motion of the bellows is transmitted to the pen staff through a linkage and rack and pinion. A small bronze spring on the pen staff eliminates any back-lash that may develop in the system.

The bellows is mounted vertically, so it will drain properly and a bleed screw can be provided for exhausting all air from the system, when necessary. The volume of the bellows and piping in the recorder is about 15 cu. in.

Cases

Portable, wall, flush and front switchboard single cases are available and all but portable are also furnished in twin mounting. Flush cases have 120 volt, 60 cycle fluorescent lighting. For certain other power sources, incandescent lighting can be supplied.

Chart Drives

Briefly, chart drives are divided into three general classes: hand-wound spring, motor-wound spring and synchronous. Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds of ¾, 1½ and 3 inches per second are obtained with external motor attachments.

How to Order—*Specify:*

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall mounting.

2—Chart Drive (Catalog Section 20): Hand-wound spring, Motor-wound spring, Synchronous. If electric, give voltage and frequency. If electric hour-to-minute feed shift, give voltage and frequency.

3—Measuring Element: Pressure. Give details of application, maximum possible pressure and normal range of pressure.

4—Scale and Chart: Range numbers desired on chart and scaleplate. Chart speed.

5—Accessories and Attachments (Catalog Section 80): Pressure snubber, carrying case, writing door, glass corner in case cover, chart inspector, right- and left-hand chronograph pens (give voltage and frequency).

6—Supplies (Catalog Section 90): Extra pen elements, pen points, charts, ink.

THE ESTERLINE-ANGUS CO., INC.

Pioneers in the Manufacture of Graphic Instruments

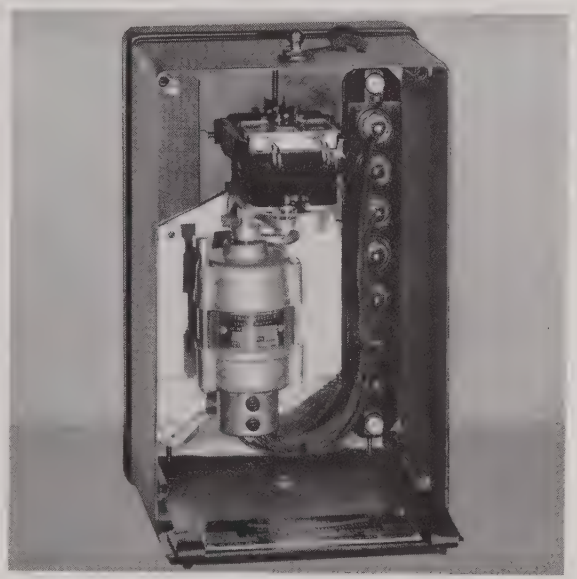
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

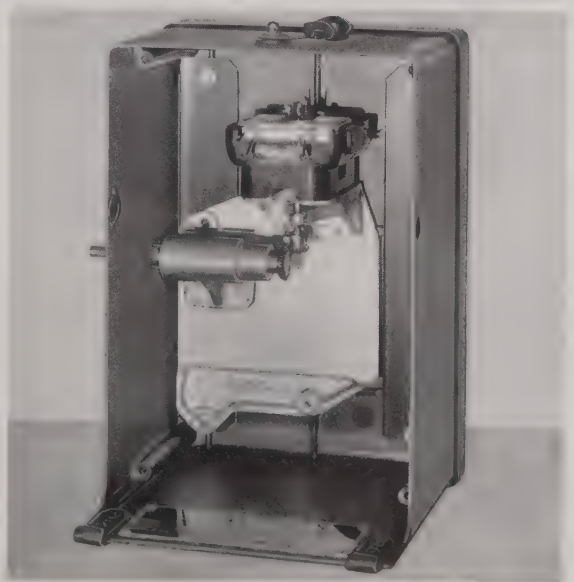
Catalog Section 60
Printed in U.S.A., 10M

Product Representatives
in Most Principal Cities

ESTERLINE-ANGUS Position and Motion *Recorders*

Mechanical and Selsyn Types





IT IS FREQUENTLY important to record such things as the mechanical position of a machine member, a damper or gate, the weight or thickness of material on a scale, or the swings made by an electric shovel. Position and motion recorders have been developed to make records of such values. They are made in two distinct types to meet installation requirements. The mechanical type is intended for use where the recorder can be mounted near the measuring point. The Selsyn or electrical recorder is intended for those installations where the reading of position, motion or thickness must be transmitted some distance to the recorder. The following examples will serve to show the usefulness of position and motion recorders:—

Damper or gate position
Valve position or opening
Ram motion (hydraulic presses)
Governor position
Platen position (flash welders)
Liquid or material level in tank or bins
Height of gas holders
Thickness of sheet or strip material
Weight recording (attached to scale)
Swing recording on power shovels and drag-lines

Mechanical Type

The mechanical recorder has a shaft extending from the left side of the case. Thirteen internal gear ratios are available to provide full scale swing of the pen with a minimum of 12.4 to a maximum of 309.5 degrees rotation of the shaft. Clockwise rotation of the external shaft, viewed from the left, moves the pen across the $4\frac{1}{2}$ inch scale. A built-in stop prevents rotation that might damage the internal mechanism.

The external shaft is $\frac{3}{8}$ inch in diameter. It is located $6\frac{1}{8}$ to 7 inches above the outside bottom level of the case, the exact distance depending on gear ratio. In a front switchboard case the shaft center line is $2\frac{11}{16}$ inches in front of the panel. In a wall case, the shaft is $4\frac{11}{32}$ inches in front of the wall. In a flush case, the shaft is 6 inches behind the front of the panel.

The torque required to start the recorder mechanism in motion varies from approximately 1.5 inch-ounces for 309.5° gearing to 7 inch-ounces for 12.4° gearing.

Method of Drive

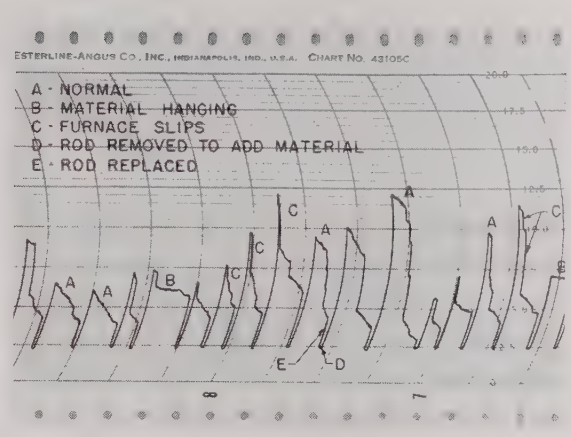
A rotary motion can be recorded by direct or gear connection to the external shaft. Straight line motion can be recorded by a rack and pinion, cable and drum or sprocket and chain. If a drum is used, flat tape instead of cable should be employed where the drum diameter is less than about 2 inches. External gearing can be used to accommodate motion that would produce more than 309.5° rotation of the shaft. A spring or weight should be included to take up slack or backlash in the external mechanism.

Selsyn Type

The Selsyn recorder has a receiving Selsyn inside the case, geared to the pen staff. Ten gear ratios are available so that a minimum of 62° to a maximum of 345° rotation of the Selsyn will produce full scale pen travel. The recorder is actuated by a transmitting Selsyn located at the measuring point and arranged to rotate in direct relation to the motion or position to be recorded. Starting torque required is very slight.

Voltmeter as a Position Recorder

Motion and position are sometimes recorded by using a voltmeter, a potentiometer and a constant-voltage source. The recorder reads the voltage drop between the sliding contact and one end of the potentiometer. Center-zero voltmeters are often used on electric shovels in place of the mechanical recorder, to make a production record.

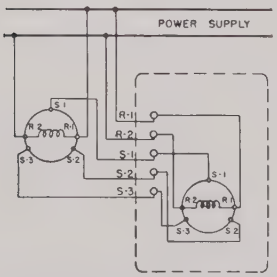

ESTERLINE-ANGUS CO., INC., INDIANAPOLIS, IND., U.S.A. CHART NO. 43105C
A - NORMAL
B - MATERIAL HANGING
C - FURNACE SLIPS
D - ROD REMOVED TO ADD MATERIAL
E - ROD REPLACED

Record from a Selsyn position recorder used as a "Stockline" recorder in a blast furnace. A rod, which is automatically raised to a fixed position each time the furnace is charged, rides on the material in the furnace and follows the surface down as melting progresses

Chart Drives

Briefly, chart drives are divided into three general classes: hand-wound spring, motor-wound spring and synchronous. Each type can provide chart speeds of ¾, 1½, 3, 6 and 12 inches per hour and per minute. Higher chart speeds of ¾, 1½ and 3 inches per second are obtained with external motor attachments.

Position and Motion Recorders



Internal and external connections of Selsyn recorder

Rotation for Full Scale Deflection

Mechanical (External Shaft)	Selsyn* (Transmitter Shaft)
12.4°	62°
15.5°	80°
20.6°	90°
31.0°	100°
41.3°	120°
46.4°	135°
61.9°	150°
82.5°	200°
92.8°	270°
123.8°	300°
185.7°	345°
247.6°	
309.5°	

*Both transmitting and receiving Selsyns are GE 2JD55, 120 volts, 60 cycles only.

Charts—Uniform. 4300 series, see Catalog Section 90.
Scale—To match any 4300 series chart. Scale must be selected so maximum motion will be less than full scale.
Guaranteed Accuracy—Mechanical, 0.5% of full scale rotation. Selsyn, 0.5 to 2% of full scale rotation, depending on gear ratio.

How to Order—*Specify*

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall Mounting.

2—Chart Drive (Catalog Section 20): Hand-wound spring, Synchronous, Motor-wound spring. If electric give voltage and frequency. If electric hour-to-minute feed shift desired, give voltage and frequency.

3—Measuring Element: Mechanical or Selsyn (120 volts, 60 cycles only). Give degrees rotation for full scale.

4—Transmitting Selsyn—Are we to furnish?

5—Scale and Chart: Range numbers desired on scale and chart. Chart speed.

6—Accessories and Attachments (Catalog Section 80): Writing door, glass corner in case cover, chart inspector, right- and left-hand chronograph pens, (give voltage and frequency).

7—Supplies (Catalog Section 90): Extra pen elements, pen points, charts, ink.

THE ESTERLINE-ANGUS COMPANY
Pioneers in the Manufacture of Graphic Instruments
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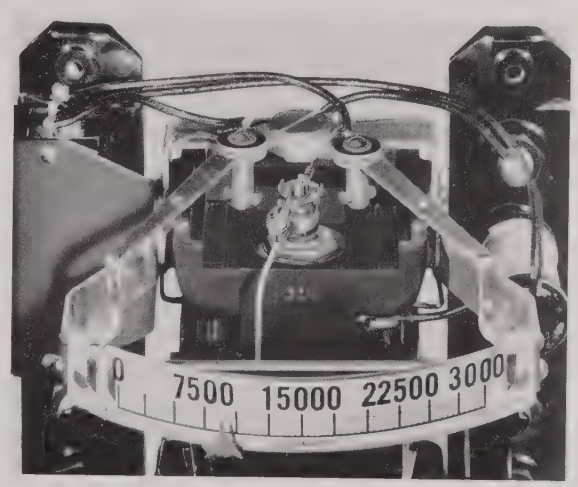
Product Representatives in Most Principal Cities

ESTERLINE-ANGUS

Contact-Making

Instruments



CONTACT-MAKING INSTRUMENTS are intended for use wherever rugged, heavy-duty relays with easily and accurately adjustable contacts are required. They employ the same high-torque measuring elements used in the corresponding E-A recorder. The contact instrument has adjustable high and low contacts, illustrated at the right, that can be set at any point on the scale. The indicating pointer carries a spring-mounted, center (common) contact which is held captive between the settings of the high and low contacts. The contacts will carry up to ¼ ampere at 250 volts maximum, AC or DC. To protect the contact circuit, a fuse is provided in the common contact lead.

The adjustable contacts are mounted on arms which have index pointers extending over the indicating scale. Contacts are set simply by moving the contact arms as shown at the right. On meters housed in front switchboard or wall cases, outside adjusting knobs can be furnished as shown in Fig. 3.

Contact-making voltmeters are often used to initiate action of the high-speed external drives on graphic voltmeters for recording power system faults. The contact instrument is ideal for this application. It is easy to change its "cut-in" point when necessary and its measuring element has the same speed of response as the recording voltmeter. Since the contacts will carry up to ¼ ampere, many applications can be handled without using auxiliary relays.

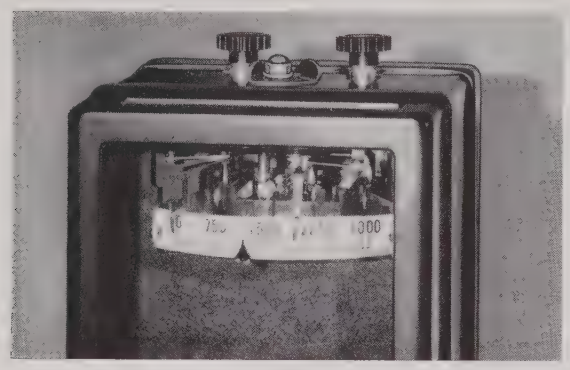


FIG. 3—*Outside contact adjusting knobs are available on instruments designed for front switchboard wall mounting*

In process control, there are many instances where a signal is desired when power, current, speed, etc. reaches a definite value. Quite often this value is changed from day to day or week to week.

Contact-making wattmeters have been used extensively in load control schemes to limit maximum demand. These range all the way from lighting a signal lamp or sounding a horn, when the plant load reaches a pre-determined value, to dropping off load automatically until the peak load is past.

How to Order—*Specify*—

1—Case Style (Catalog Section 15): Portable, Flush Switchboard, Front Switchboard, Wall Mounting. When both contact making and recording are required, the two instruments can be mounted in a twin case.

2—Measuring Element: See catalog section for corresponding recorder and give ordering details.

3—Contacts: Will AC or DC be used?
Outside adjustment: (Front switchboard and wall cases only).

Contact Making Instruments

TYPE	Basic Instrument Described in Catalog Section
AC Ammeter	30
DC Ammeter	40
Frequency	38
KVA	35
KVAR	35
AC Milliammeter	48
DC Milliammeter	42
Power Factor	37
Tachometer	46
AC Voltmeter	30
DC Voltmeter	40
AC Wattmeter	33
2-Current Element	
3-Current Element	
4-Current Element	
DC Wattmeter	33

Scale—Same as corresponding recorder.

Contact Adjustments—Adjustable by moving contact arms inside the case. Meters in wall and front switchboard cases can be supplied with outside adjusting knobs.

Contact Rating—¼ ampere, 250 volts maximum. To protect the contact circuit, a ½ ampere fuse is provided in the common contact lead. Specify whether AC or DC is to be used on contacts. An arc suppression circuit is used for DC applications.

Contact Setting—Total "spread" between contacts should preferably be 10% or more of scale width.

Installation and Application—Mounting location must be free of vibration. An auxiliary relay must be used for currents exceeding ¼ ampere or voltage above 250. Use lock-in relay, such as, Struthers-Dunn 8BXX50, or other sensitive instrument relay where possible.

Guaranteed Accuracy—Same as corresponding recorder plus 1%. For example, the guaranteed accuracy of a recording AC Ammeter is ± 1% of full scale current. The same mechanism in contact-making form is guaranteed to open or close its contacts at the value for which the adjustable contact arm is set on the scale ± 2% of full scale value.

Dielectric Test—Measuring element, same as corresponding recorder. Contact circuits, 2000 volts, 60 cycles, for one minute.

THE ESTERLINE-ANGUS COMPANY
Pioneers in the Manufacture of Graphic Instruments
P. O. BOX 596, INDIANAPOLIS 6, INDIANA

ESTERLINE-ANGUS
Recording Instrument
Accessories and Attachments

The usefulness of a graphic instrument is greatly increased through the purchase of accessories and attachments carefully matched to the recorder characteristics. Esterline-Angus instruments are required to operate under a variety of conditions, and the accessories and attachments on the following pages have been developed to have the same adaptability. Their use in combination with Esterline-Angus recorders will assure the greatest possible accuracy and dependability.

Current and Potential Transformers
Single and Multi-purpose,
Portable and Switchboard Types
KVA-KVAR Phase Shifting Networks

Shunts

Chronograph Pens (Event Markers)

Glass Corner in Case Cover

Carrying Cases

Quick-Connectors

Cable Clamps

Chart Inspector

Writing Door

Electrical Counters

For Charts and Writing System Supplies
See Catalog Section 90

Catalog Section 80
(April 1960)

Portable Universal Current Transformer

7 Ranges

These transformers are designed primarily for use with graphic instruments and, to provide the versatility required in such service, they have a variety of ranges. The ratings are: 10, 25, 50, 100, 200, 400 and 800 amperes primary to 5 amperes secondary.

Rugged Construction

Transformers are often subjected to rough handling. To give the Model D transformer the ruggedness required to withstand such service, it is enclosed in a substantial cast aluminum case. Terminal studs are large and sturdy to stand mechanical shock without breaking.

High Insulation

High quality insulating materials are used between windings, between windings and core, and between windings and case.

After the transformer has been assembled and all connections made, moisture is driven out of the complete assembly by heat. While still hot, the entire case is filled with compound to prevent re-entry of moisture.

Each transformer is then subjected to a high voltage test of 10,000 volts AC between primary and secondary, and between the primary and the case. A test of 5000 volts is applied between the secondary and the case. Since the Universal current transformer is rated for use on circuits which do not exceed 2500 volts, there is an ample factor of safety.

Simple Connections

The four lower ratings: 10, 25, 50 and 100 amperes, are obtained with a tapped wound primary. Each rating has a marked terminal and there is one common terminal for these four ranges. The 800,400 and 200 ampere ranges are obtained by threading the conductor which acts as the primary through the hole in the core 1, 2 and 4 times respectively. Conductors used in this manner must be insulated.

High Accuracy

For maximum usefulness, a transformer must have an accuracy comparable to the instrument with which it is used. To gain this attribute, the core of this transformer is assembled of the best grade, oriented grain electrical steel. This results in minimum phase angle shift and more stable ratios.

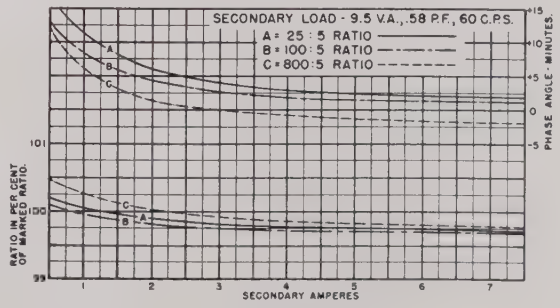
The accuracy class of this transformer is ASA 0.6, B-0.5 and B-1. Typical phase angle and ratio curves are shown in the illustration below.

Ample Capacity

The Model D transformer has sufficient capacity to operate several graphic instruments, as well as indicators, so it is seldom necessary to have separate transformers for each recorder. The secondary rating is 25 volt-amperes, compensated for 15 volt-amperes.

The wound primary ranges of this transformer will carry 30% continuous overload, while the through ranges will withstand 70% continuous overload. Permissible short time overloads on any range are 38 times rating for one second and 17 times rating for five seconds.

The frequency rating is from 25 to 125 cycles at rated capacity. Operation at higher frequencies, up to 800 cycles, is usually possible.


SECONDARY LOAD - 9.5 V.A., .58 P.F., 60 C.P.S.
A = 25 : 5 RATIO
B = 100 : 5 RATIO
C = 800 : 5 RATIO
PHASE ANGLE - MINUTES
RATIO IN PER CENT OF MARKED RATIO
SECONDARY AMPERES

Typical ratio and phase angle curves are shown above for the 25, 100 and 800:5 ampere ranges. Curves for the other ranges lie so close to these that they have been omitted for readability. The curves were made with the burden of a standard E-A 2-element AC wattmeter, but will also apply for most other instrument burdens.

Overall Dimensions: 5¾ x 8¼ x 9½ inches
Secondary Short Circuiting Switch is provided
Cable Opening: 1 7/16 x 3 3/16 inches
Weight: 24 pounds
Shipping Weight: One—40 lbs.; Two—60 lbs.
Normally a Stock item

When ordering, Specify *Esterline-Angus Model D Universal Current Transformer.*

Portable Split-Core Current Transformer

Annis split-core current transformers are intended primarily to measure current in 50 or 60 cycle circuits where it is not feasible or possible to open bus bars or cables and connect a solid-core transformer. These transformers are available in several sizes and current ratings. The most popular size has primary ratings of 150/300/600 amperes and is mounted on frame "A" as indicated in the table of specifications.

They are designed specifically for use with Esterline-Angus dynamometer type AC ammeters and AC wattmeters which have a 60 cycle burden of approximately 10 VA. They can, however, be used with other recording, indicating or integrating instruments imposing approximately the same burden provided the primary current rating is 250 amperes or above.

The unique inter-leaved joint on the transformer core results in much lower reluctance and magnetizing current than can be obtained with butt-joint cores. This construction improves the ratio and phase angle characteristics and prevents dirt from affecting the accuracy. High-grade, annealed silicon-sheet laminations are securely clamped in an aluminum housing. The coils are accurately wound and impregnated against moisture, and withstand an insulation test of 2500 volts AC between winding and frame. The core is positively secured in the closed position with a locking pin but can be opened quickly for clamping over a cable or bus bar.

Frame Size	Rating in Amperes	Window Opening	Weight Pounds
A	50/100/200:50 MA*†	1 9/16 x 3 3/8"	11
A	150/300/600:5*	1 9/16 x 3 3/8"	11
A	250/500/1000:5*	1 9/16 x 3 3/8"	11
C	500/1000/2000:5*	3 1/4 x 4 1/2"	26
C	500/1000/2500:5	3 1/4 x 4 1/2"	26
D	1000/2000/3000:5*	4 1/2 x 6 1/2"	35
E	1000/2000/4000:5	2 1/4 x 8 1/2"	36
E	1000/2000/5000:5	2 1/4 x 8 1/2"	36
DL	1500/3000/6000:5	3 1/4 x 6 1/2"	44

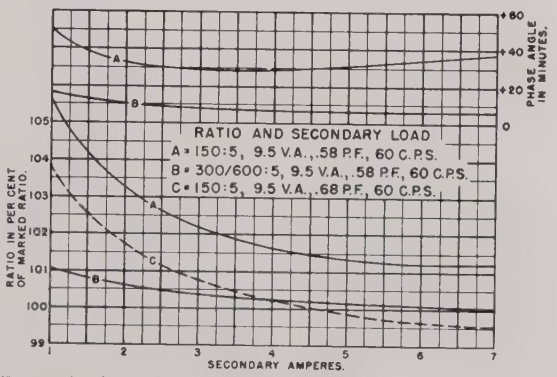
*Normally carried in stock
†Special transformer for use only with multi-purpose recorder having 0-50 MA AC range.

These transformers are metal clad, thus sufficient insulation between cables or bus bars and the frame of the transformer is required to withstand the voltage between the primary circuit and ground. A short-circuiting switch is provided on transformers in which the open-circuit voltage is high enough to require one.

Overload Capacity and Accuracy

Transformers on frame "A" will withstand 100% overload continuously; the larger transformers will withstand 35% overload continuously.

All 5-ampere models are compensated for a 10-volt-ampere burden. When used with the E-A dynamometer type AC ammeter (measuring element 316) rated 0-5, or one element of the E-A 2-element AC wattmeter (measuring element 330), errors caused by the transformer will not exceed 1 to 2% of full scale, even on the lowest ratio (150:5 amperes), and will be less when using the higher ratios. Typical 60 cycle ratio and phase angle curves are shown in the accompanying illustration.



Curves A, above, show phase angle and ratio errors for the 150:5 ampere range used with one current element of an E-A standard 2-element AC wattmeter. The same average data for the 300 and 600:5 ampere ranges are shown in curves B, while curve C shows the ratio error for the 150:5 ampere range used with an E-A 5-ampere dynamometer type AC ammeter.

Special Transformer For Low Currents

A special split-core transformer with primary ratings of 50, 100, 200 amperes is available for use with the multi-purpose recorder calibrated for 50 MA AC full scale. The transformer has a 50 MA secondary and consequently cannot be used with 5-ampere instruments. It has a 100% continuous overload capacity and it can be used on circuits with a frequency of 50 to 800 cycles. Catalog section 48 describes this special transformer and the multi-purpose recorder.

When ordering, specify rating and frame size shown in table.

Switchboard Mounting Indoor Dry Type Current Transformers

With Through Primary

Type: Westinghouse H2.5 or FB, with rectangular opening for bus bars.

Ratings: 5000 ampere ratings and below: usable on 25-60 cycle circuits up to 2500 volts. 7500 ampere ratings and above: usable on 25-60 cycle circuits up to 600 volts. Capacity, all ratings: 50 VA.

Accuracy: ASA system: 0.3 to 0.6 class, burdens B 0.2, B 0.5 and B 2.

Amperes	Ratio	Window Opening
800:5	160:1	3⅛ x 1 1/16″
800:5	160:1	4⅛ x ⅞″
1200:5	240:1	3⅛ x 1 1/16″
1200:5	240:1	4⅛ x ⅞″
1500:5	300:1	3⅛ x 1⅞″
1500:5	300:1	4⅛ x 1⅜″
2000:5	400:1	3⅛ x 1⅞″
2000:5	400:1	3⅛ x 3⅜″
2000:5	400:1	4⅛ x 1⅜″
3000:5	600:1	3⅛ x 3⅜″
3000:5	600:1	4⅛ x 4⅛″
4000:5	800:1	4⅛ x 4⅛″
4000:5	800:1	6⅛ x 2 1/16″
5000:5	1000:1	4⅛ x 4⅛″
5000:5	1000:1	6⅛ x 2 1/16″
7500:5	1500:1	6⅛ x 4½″
10000:5	2000:1	6⅛ x 4½″
15000:5	3000:1	6¼ x 6¼″

With Wound Primary

Type: Sangamo MA-50, Westinghouse SM-5, Allis-Chalmers MKE.

Ratings: All listed ratings usable on 25-60 cycle circuits up to 5000 volts. Some are usable on higher frequencies. Capacity, all ratings: 50 VA.

Accuracy: ASA system: 0.3 class, burdens B 0.1, B 0.5 and B 2.

Amperes	Ratio
10:5	2:1
15:5	3:1
25:5	5:1
40:5	8:1
50:5	10:1
75:5	15:1
100:5	20:1
150:5	30:1
200:5	40:1
300:5	60:1
400:5	80:1
600:5	120:1
800:5	160:1

E-A Totalizing Current Transformers

These special transformers are used where it is desired to totalize watts, KVA or KVAR on two or more AC circuits having current transformers whose ratios are not alike and/or whose secondaries cannot be paralleled. The totalizing transformers are specially designed for each installation and can be furnished with 2 to 8 primary windings and a 5 ampere secondary. Consult factory and page 7, Catalog Section 33.

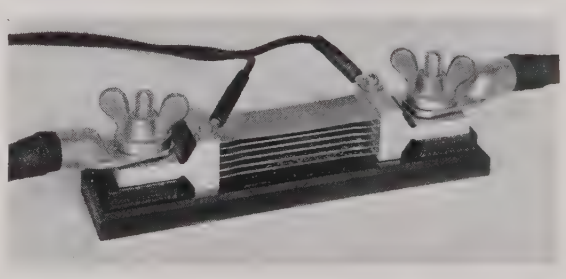
Shunts for DC Ammeters and Wattmeters

Rating* (Amperes)
¼
½
1
2
5
10
25
50
100
150
200
250
300
400
500
600
750
1000
1500
2000
2500
3000
4000
5000
6000
8000
10000

E-A shunts are of the finest design and construction. Lugs are of cast copper. The blades are manganin which has negligible change in resistance over a wide change in temperature and only a very slight thermal EMF against copper. Portable shunts are made in sizes ¼ to 5000 amperes; switchboard shunts in sizes ¼ to 10,000 amperes.

Unless otherwise specified, shunts have 100 MV drop at rated line current. Shunts rated 50 MV can be supplied. Ratings up to 300 MV can be furnished for special applications.

E-A shunts are guaranteed to ½% accuracy. The current drawn by the meter is taken into account in calibrating all ammeter shunts up to 50 amperes capacity and wattmeter shunts up to 1000 amperes, 3 wire and 2000 amperes, 2 wire. Shunts have no continuous overload capacity and should be selected with a rating about 25% above full load current.



Portable shunts are mounted on insulating bases.

Standard slotting on shunts of 2500 ampere capacity and larger is ¼ inch slot and ¼ inch spacing.

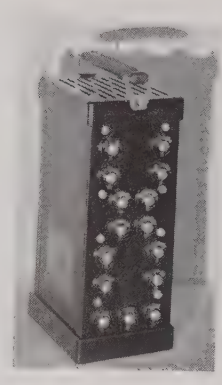
In ordering, it is necessary to state whether shunts are for a DC ammeter, DC or AC-DC wattmeter and whether the system is 2 or 3 wire. If ordering for an existing meter, give serial number.

For further information about DC ammeters and DC and AC-DC wattmeters, refer to Catalog Sections 40 and 33 respectively.

*10-2000 ampere sizes normally stocked in semi-finished form.

Potential Transformers

*KVA-KVAR



The E-A Model A phase shifting transformer is designed to supply the potential circuits of an AC wattmeter to permit measurements of KVA or KVAR. It can be used on 25, 50 and 60 cycle circuits at 120 volts and on 50 and 60 cycle circuits at 240 volts. It consists of two circuits each of which has a 25 VA capacity and is compensated for 8 VA. For KVA, three sets of taps are provided to permit recordings within various power factor ranges as follows: 0.75 to 0.95, 0.64 to 0.95, 0.53 to 0.85. A fourth set of power factor taps, 0.89 to 1.00, can be added on special order. The Model A phase shifting transformer measures 6½ x 6½ x 13 inches and can be provided in portable cases, or for wall or switchboard mounting.

*KVAR

The E-A Model B phase shifting transformer when used in the potential circuits of a wattmeter will permit KVAR recordings on 120 volt 60 cycle circuits. 240 and 480 volt 60 cycle circuits can be accommodated by using the double potential transformer described below. The Model B transformer has two circuits, each with a capacity of 15 VA, compensated for 8 VA. It is available in a case measuring 3½ x 5½ x 12 inches designed for switchboard mounting.

*Double Potential Transformer

This E-A unit derives its name from the fact that two identical potential transformers are mounted in one case measuring 6½ x 6½ x 13 inches. Each of these transformers is rated 240/480:120 volts 50-60 cycles and has a capacity of 40 VA, compensated for 10 VA.

The unit is designed for use with the Model A phase shifting transformer on 480 volt 50-60 cycle circuits and the Model B phase shifting transformer on 240 or 480 volt 60 cycle circuits. It can also be used with wattmeters having only a 100 volt potential calibration to permit recording of 240 or 480 volt 50-60 cycle circuits.

*Isolating Transformers

These E-A transformers are designed for KVA-KVAR measurement where it is necessary to have an isolated secondary circuit. It is rated 120:120 V, 50-60 cycles, has a capacity of 50 VA, and is compensated for 10 VA. It is available in portable and switchboard cases 6½ x 6½ x 13 inches in size.

*Step-up Potential Transformers

These E-A transformers permit recordings of low AC voltages as, for example, the recording of welding arc voltages. They can be furnished in portable or switchboard cases. Two types are available:

Voltage Rating		Frequency	Capacity	For Use With
Primary	Secondary			
25/50/75	150	50-60	20 VA	E-A 0-150 Volt AC voltmeters and multi-purpose recorder
5/15/30	150	60	15 VA	Same as Above

Control Transformers

For use where exact ratio is not required, E-A supplies control transformers. These are rated 240/480:120 or 120:24 volts, 60 cycles, and have a 100 VA capacity. They are designed for wall mounting and have a knockout box for conduit connections.

Switchboard Indoor Dry Type Transformers

Type: Westinghouse PT or EMPL and Allis-Chalmers PD, with fuse blocks.

Ratings: All listed ratings usable on 60 cycle circuits. Capacity listed below.

Voltage Rating		Ratio	Capacity
Primary	Secondary		
240	120	2:1	75 VA
480	120	4:1	75 VA
600	120	5:1	75 VA
2400	120	20:1	200 VA
4800	120	40:1	200 VA

Portable Dry Type Transformers

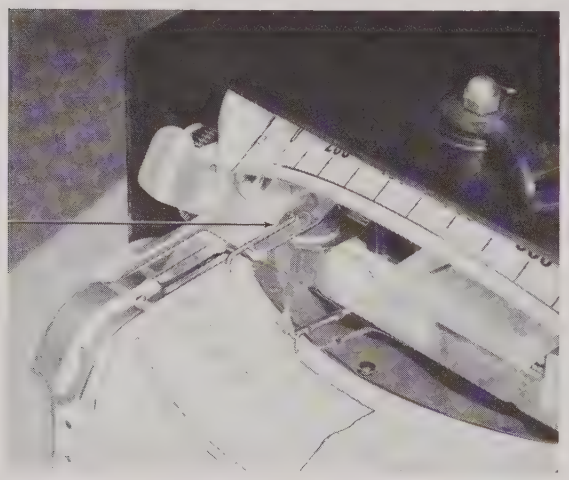
Type: General Electric E6, JE9 and Westinghouse PV-130.

Frequency	Voltage Rating	Capacity
50-60 cycles	600:120	25 VA
50-60 cycles	*2400/4800:120	100 VA
60 cycles	240/480/600:120	100 VA
60 cycles	*600/1200/2400:120	75 VA†

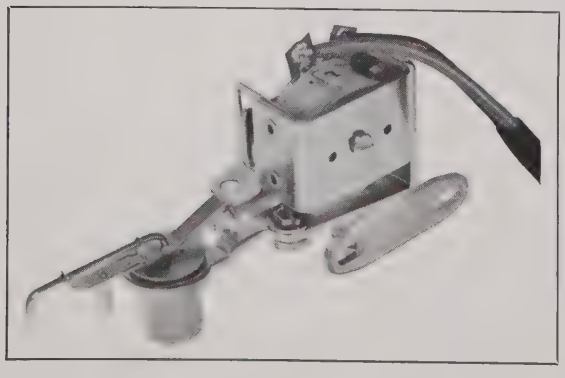
†75 VA on higher ratios; 20 VA on 600:120 ratio
**Normally Carried in Stock*

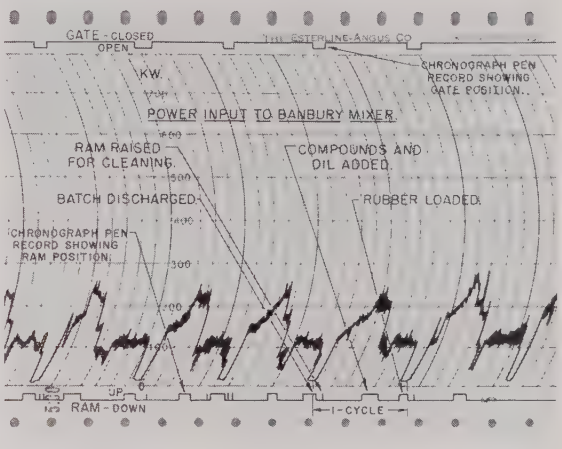
Chronograph Pens (Event Markers)

A chronograph pen is an electromagnetically operated pen that can be mounted to record in the margin of an AW recorder chart. It is highly useful for keying some event to the main record. For example, if a voltage record were being made of a feeder line, a chronograph pen could answer questions about a particular motor on the line: *when* did it begin running, *how long* did it run, and *how many times* did it start and stop during a particular period? Also, chronograph pens actuated simultaneously on several charts provide common reference points.



The picture above shows a chronograph pen positioned to record in the left-hand margin of a chart. Another such pen can be mounted to record in the right-hand margin. The electromagnet-pen assembly is shown in the picture below. The pen moves about 1/10 inch toward the edge of the chart when voltage is applied and it returns to the normal "off" position when voltage is interrupted. The pen assembly can follow ten complete on-off cycles in one second. The electromagnet can be furnished to accommodate any of the standard voltages listed in the accompanying table, or any special intermediate voltage which falls in the ranges 2-250 V DC or 6-240 V, 50-60 cycles.





The typical chart above shows power input to the driving motor of a Banbury mixer used to blend ingredients used in making rubber. Chronograph pens have been used to show operation of the gate and ram on the mixer. The ram forces the material against the rolls; the gate opens to permit a batch of rubber to be dumped. The time from the closing of the gate to the next opening is mixing time. Uniformity of mixing cycles can be also seen immediately by looking at the record of the pen monitoring the gate.

Electromagnet Specifications

Rated Voltage*	Coil Style	Milli-amperes	Watts per Circuit	Ohms per Coil (DC)	Ohms in Series With Coil
Direct Current					
2 Volts	N	570	1.1	3.5	None
4 Volts	K	286	1.1	14	None
6 Volts	J	231	1.4	26	None
8 Volts	G	131	1.0	61	None
10 Volts	F	99	1.0	101	None
12 Volts	F	119	1.4	101	None
14 Volts	E	90	1.3	156	None
16 Volts	D	67	1.1	238	None
18 Volts	D	76	1.4	238	None
24 Volts	C	65	1.6	372	None
28 Volts	B	42	1.2	666	None
32 Volts	A	29	0.9	1092	None
48 Volts	T	29	1.4	1650	None
125 Volts	B	41	5.2	666	2400
250 Volts	T	26	6.5	1650	8000
50-60 Cycles AC					
6 Volts	N	447	1.6	3.5	None
12 Volts	K	233	1.7	14	None
24 Volts	G	103	1.5	61	None
120 Volts	T	20	1.5	1650	None
240 Volts	T	21	4.5	1650	7000

*All electromagnets are guaranteed to operate at voltages 15% above or below rating.

Although it is preferable to install chronograph pens when the instrument is built, they can be added with little difficulty to Model AW recorders already in service. Complete installation instructions are furnished with each pen assembly. ***When ordering***, specify right or left-hand pen, voltage, frequency and, if for field installation, the instrument serial number.

Writing Door

All case styles, except twin flush switchboard, can be equipped with a writing door as illustrated at right. This door slides open to permit writing directly on the chart without opening the case cover. The flat instruction plate for the chart drive forms the writing surface behind the chart.

Glass Corner

Where the recorder is installed below eye level and the usual solid corner of the case cover obscures the view of the scale and pen, the glass corner, shown at the left, is a convenient feature.

Glare Reducing Glass

Sometimes, light reflecting in the front glass of a recorder's cover makes it difficult to read the chart. To eliminate this trouble, E-A furnishes a special glare reducing glass to replace the front glass in recorder cases without the writing door described above.

Laminated Safety Glass

If the recorder is to be used where there is the possibility of an external object striking the front glass in the cover, it is recommended that laminated safety glass be used. This can be furnished for instruments without a writing door.

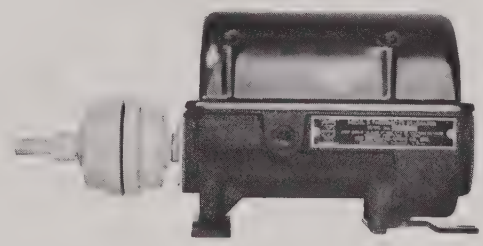
Selsyn Transmitters

For use with the E-A selsyn type position recorder (Catalog Section 65) and for the selsyn powered E-A chart drive (Catalog Section 20), E-A supplies the General Electric type 2JD55, 120 V, 60 cycle selsyn transmitter.

Chart Feeding Slot

It is sometimes convenient to let the chart feed out of the bottom of the case so it can be torn off after each shift or test. This feature (right) can be obtained at will on portable, front switchboard and wall cases simply by removing the rubber gasket at the bottom of the cover. As a special feature, flush cases can also be modified so the chart can be fed out in front of the panel.

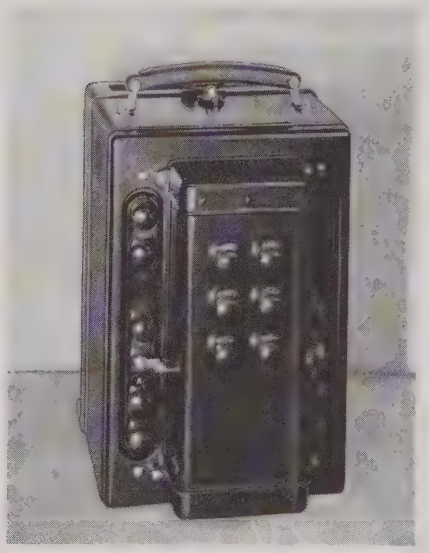
Flexible Coupling



For installations where it is desired to directly connect a tachometer generator to a driving shaft, E-A offers the flexible coupling and stud shown in the picture above. This coupling, of the pin and leather disc type, is approximately 3¼ inches in diameter. It will take care of ordinary lateral or angular misalignment and will permit a maximum of ½ inch longitudinal motion between the generator and the driving shaft. The stud can be furnished for clockwise, counterclockwise, or reversing shaft rotation.

Pulleys

For use in coupling the E-A tachometer generator to driving shafts via a flat belt drive, E-A supplies two inch and four inch diameter pulleys bored for a ⅝" shaft and slotted for a No. 5 Woodruff key. These pulleys are made of a durable glass-filled resin compound. For information on the use of the flexible coupling and pulleys, refer to Catalog Section 46.



*Binding Posts:

←

Can be used on portable recorders in place of leads, except on DC ammeters, multi-purpose recorders with a millivolt calibration and the current circuits of DC and AC-DC wattmeters.

No. 8896 Large Binding Post, 5/16-24 thread.

No. 8897 Small Binding Post, 10-32 thread.

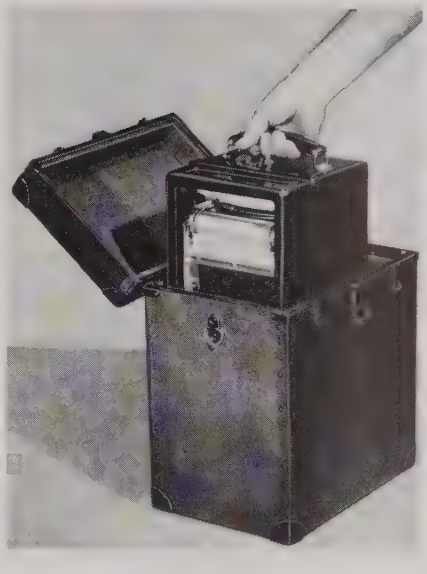
*Carrying Cases

→

For convenience in transporting a portable AW recorder, a black fibre case, felt lined, with hinged lid and lock is available. If ordering for an existing meter, give serial number.

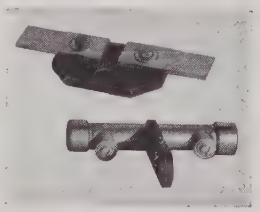
No. 23—For any standard meter with or without standard size attached multiplier.

Series 8900—For recorders having additional or deep-style multiplier boxes or external motor drives.



*Quick Connectors

Type	Fuse Block Size		
	Amps.	Type Number	
		250 Volt	600 Volt
Ferrule	60	F-22	F-62
Knife	100	K-21	K-61
Knife	200	K-22	K-62
Knife	400	K-23	K-63
Knife	600	K-24	K-64



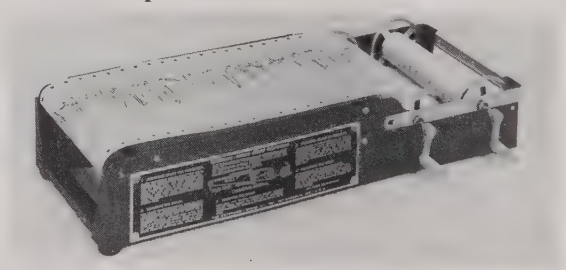
Quick Connectors are the same size as standard fuses. They permit rapid connection of a recorder current circuit, a current transformer, or a shunt merely by removing the fuse from the block and replacing it with a Quick Connector. For maximum safety, a duplicate set of fuses should be used so the circuit does not remain unprotected.

*Cable Clamps

No.	Maximum Diameter of Cable
C-11	½ inch
C-22	1 inch
C-33	1½ inch

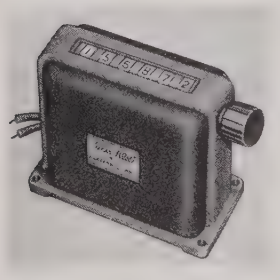
For convenience in connecting the potential circuits of recorders to insulated cables, cable connectors are furnished. They consist of a bronze yoke with a pointed, hardened-steel screw and lock nut. They are not insulated, so care must be exercised in using them.

*Chart Inspector



A convenient device, with two rollers and two cranks, for examining record charts or portions of them. A table on top provides for writing on the chart.

*Normally carried in stock



Electrical Counters

Ratings:
24 volts DC
120 volts DC
24 volts, 60 cycles
120 volts, 60 cycles
240 volts, 60 cycles
(Veeder-Root, Inc.)

Six figures. Electrically operated, consume about 8 watts, will register as rapidly as 600 operations per minute. For totaling operations of a chronograph or operation recorder pen.

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CHARTS

and

Writing System Supplies

for all models of

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The finest recorders, with the most accurate measuring elements and precision chart drives are rendered useless unless the vital combination of charts, ink and writing system is equally well engineered. Each manufacturer has worked out by diligent research the combination that works best in its particular recorder. Best performance results from using E-A charts, ink and writing system supplies in E-A recorders.

THE ESTERLINE-ANGUS COMPANY

"The Meter With a Record" for Over 50 Years

P. O. BOX 596, INDIANAPOLIS 6, INDIANA

Catalog Section 90

(February 1960)

Writing System Parts and Supplies

Ink

Recorder ink, especially prepared for use in the E-A writing system is available in red or green color in 2-ounce, 1 pint and gallon bottles.

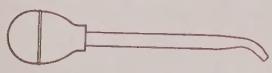
Accessory Kit

The AW Accessory Kit is housed in a cardboard box as shown above. Each kit contains a 2-ounce bottle of ink, pen filler, inkwell filler and pen point cleaner.

Pen Point Cleaner

Pen Filler

Inkwell Filler

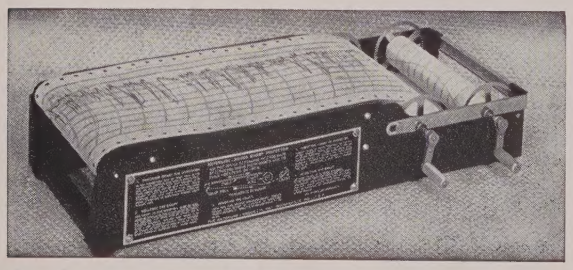


Pen point cleaner, pen filler and inkwell filler can be purchased separately or in the kit, above

Pen Points

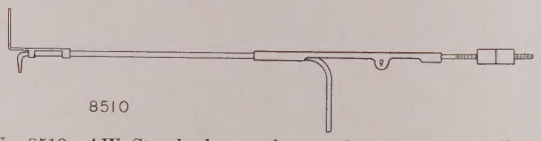
No. 82-M—Replaceable pen points. These are illustrated in pen elements 8510, 9056 and 9112 in the next column.

Chart Inspector



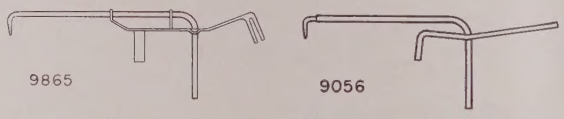
The chart inspector is a convenient tool for inspecting records, making notes on them and re-rolling them for filing.

Pen Elements



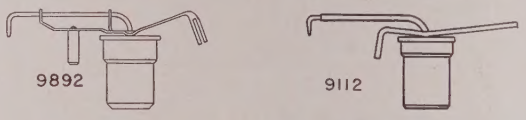
No. 8510—AW Standard pen element for ammeters, milliammeters, voltmeters, wattmeters, etc. 6 5/16″ long over-all.

No. 3154—LR-MS Standard pen element, 5 7/8″ long over-all. (Not illustrated but similar to No. 8510)



No. 9865—One-piece, for AW operation recorders above serial No. 30782 (supersedes 9856 which had a replaceable pen point).

No. 9056—For AW operation recorders below serial No. 30782.



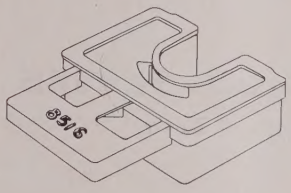
No. 9892—AW chronograph pen element and inkwell assembly. Give serial number.

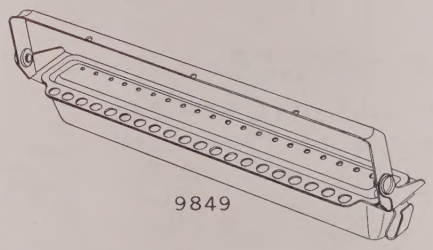
No. 9112—AW chronograph pen element and inkwell assembly. Give serial number.

Inkwells

No. 8516—AW Standard inkwell with cover.

No. 4038—(Not illustrated)—LR Standard inkwell with cover.





No. 9849—Inkwell with stainless steel body, for AW operation recorders above serial No. 30782.

No. 9050—For AW operation recorders below serial No. 30782. (Not illustrated)

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